Boyle & Spierling

Tests of water motors

Mechanical Engineering

B. S.

1910

TESTS OF WATER MOTORS

BY

CLARENCE BOYLE, JR.
ARTHUR OTTO SPIERLING

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE

IN MECHANICAL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

OF THE

UNIVERSITY OF ILLINOIS

JUNE, 1910

UNIVERSITY OF ILLINOIS

May 31 1910

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Clarence Boyle Jr. and Arthur Otto Spierling

ENTITLED Tests of Water Motors

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

H. L. Whittemore

Instructor in Charge.

APPROVED: G. A. Goodenough

HEAD OF DEPARTMENT OF Mechanical Engineering

TABLE OF CONTENTS

	Page
INTRODUCTION	1
HISTORY OF DEVELOPMENT OF WATER MOTORS	2
THEORETICAL CONSIDERATIONS	5
OUTLINE OF TESTS	6
PREPARATION FOR TESTS	8
METHOD OF CONDUCTING TESTS	11
DISCUSSION OF CALCULATIONS AND CURVES	13
DISCUSSION OF DATA	16
CONCLUSIONS	18
BIBLIOGRAPHY	21
PHOTOGRAPHS AND CUTS OF APPARATUS	25
MISCELLANEOUS DATA SHEETS AND CURVES	33
DATA SHEETS FOR DOBLE MOTOR	40
DATA SHEETS FOR PELTON MOTOR	80
EFFICIENCY CURVES FOR DOBLE MOTOR	100
EFFICIENCY CURVES FOR PELTON MOTOR	109
EFFICIENCY SURFACES FOR BOTH MOTORS	115

INTRODUCTION.

At this time, when the preservation of natural resources is of such general interest, it is but natural that the capitalist and engineer, as well as the general public, should turn to water power development. From the present rate at which fuel is being consumed, it is evident that some time in the future modern civilization will have to depend upon something more lasting than coal, oil or other fuels to supply the energy necessary to keep the wheels of progress in motion. From present indications the utilization of water power is the logical solution of the problem. For this reason it is hoped that a careful investigation of the performance of the Doble and Pelton Water Motors, two of the most popular and representative designs of the impulse type, will be of sufficient value to justify the acceptance of this thesis.

HISTORY OF THE DEVELOPMENT OF WATER MOTORS.

Water motors are by no means of recent invention, although all of the present refinements have been brought about within the last twenty-five or thirty years. Perhaps the earliest authentic record of a water wheel as applied to grinding corn is 85 B.C. Undoubtedly crude horizontal water wheels were known even before this date. Those of vertical design appear to have been known to the ancients at a very early period, being chiefly used to raise water for purposes of irrigation. Examples of such wheels in their original form and use are still to be seen on the Nile and the Euphrates.

For the sake of historical continuity, it may be mentioned that in 1581 a pump operated by a float wheel was established at London Bridge to supply the city of London with water. In 1675 an elaborate pumping plant driven by water wheels was established on the Seine River near St.Germain. In our own country one of the first applications of water power was the old tidal mill on Mill Creek, near Boston, constructed in 1631. This was followed by others and, in fact, availability of water power determined the location of the early settlement.

All of the wheels mentioned above, together with water wheels of more recent construction, may be divided into the three general classes:-

1. Gravity Wheels
2. Reaction Wheels
3. Impulse Wheels.

The first class includes the now seldom used undershot, overshot, and breast wheels; the second class is composed almost entirely of turbines; and the last includes the impulse water wheels upon which these tests were made.

The earliest scientific consideration of impulse wheels in this country was by Jearum Atkins who, apparently, anticipated the design of the wheels of the Girard type in Europe by his design of such a wheel in 1853. Atkin's first application for a patent was rejected, though one was finally granted in 1875. These patents are simply of historical interest as his inventions have had little effect on the practical development of this type of motor.

The impulse wheel found its earliest practical development in California, where the conditions for the development of power made such a wheel necessary.

The early tangential wheel, used on the Pacific Coast, was quite simple in construction, and the development of the buckets, which began with the simpler flat and curved forms, was very largely based on the experimental method used for the development of the reaction turbine in the East. Experiments were made at the University of California, by Mr. Ralph T. Brown, as early as 1883, and the resulting bulletin, published by the department was the earliest literature on tangential wheels published in this country.

Among the names connected with the early development of the tangential bucket, Pelton and Doble are very prominent. Daniel W. Mead in "Water Power Engineering" states that the most

extensive early development of the tangential wheel was by the Pelton Water Wheel Company whose work has been so widely known and used as to make the name "Pelton Wheel" a common title for all wheels of the tangential type.

THEORETICAL CONSIDERATIONS.

It is generally accepted that the losses of energy in an impulse wheel may be grouped as follows:-

1. Energy expended in heat due to the impact of the entering water against the buckets.
2. Energy expended in heat due to the friction of the water against the bucket surfaces.
3. Kinetic energy lost due to the velocity of the water leaving the buckets.

A well designed bucket will reduce all of these losses to a minimum. In order to accomplish this,

1. The bucket surface at the entrance should be approximately parallel to the relative course of the jet, and the bucket should be curved in such a manner as to avoid sharp angular deflections of the stream.

2. The number of buckets and therefore the wetted surface should be as small as will provide for the entire utilization of the jet, since friction is proportional to the wetted surface.

3. The discharge end of the bucket should be as nearly tangential to the wheel periphery as compatible with the clearance of the bucket which follows.

Bearing these essentials in mind, the illustrations of the buckets of both motors tested show that they are designed to fulfill these requirements.

OUTLINE OF TESTS.

These tests were made in order to determine the efficiency of the motors under different conditions which occur in practice. This efficiency is the ratio of the power output to the power input. This latter depends upon the amount of water supplied to the wheel and its head or pressure. Either of these could be varied independently so the following table of heads and orifice areas was chosen to cover the available range.

Doble Motor. Effective Head (ft)	Doble Motor. Area of Orifice (sq. in.)	Pelton Motor. Effective Head (ft)	Pelton Motor. Diameter of Orifice (inches)
10	.2;.3;.4;.5;.565	20	5/8;3/4;7/8;1
20	ditto	40	ditto
30	ditto	60	ditto
40	ditto	80	ditto
50	ditto	100	ditto
60	ditto		
80	ditto		
100	ditto		

This made eight series of tests on the Doble for the different increments of head, with five tests in each series for different valve openings, or a total of forty tests on the Doble. Smaller increments of head were taken for the lower values, due to the fact these heads could be obtained from a laboratory

stand pipe while for those above 50 feet it was necessary to connect with the pumping station. With the Pelton only the large increments of head were used, five series of tests being run under different heads with four tests in each series for the different nozzles available. This made a total of twenty tests run on the Pelton or sixty tests on the two motors.

PREPARATION FOR TESTS.

Before any tests were made both motors were thoroughly overhauled. The inlet casting on the Doble Motor, containing the needle valve, was removed from the apparatus and examined. As the area of the needle valve opening, or orifice, as it will hereafter be called, was in the shape of an annular ring, its area for any given position of needle valve was rather difficult to determine. After some consideration the following method of obtaining it was used and found satisfactory.

The diameter of the orifice was first measured. Readings were then taken for various positions of the needle of its diameter in the plane of the orifice. As the two values should be the same when closed or for zero turns of the valve, these measurements were easily checked and corrected. (See curves on page 34 .)

The net area of the orifice for different positions of the needle was merely the difference between the area of the orifice and that of the needle occupying the center of it. These valves are tabulated on page 33, and the results shown by the curve on page 35 .

The next step was the calibration of the Measuring Pit E into which the tail race from both motors emptied. (See Fig. 7 , page 29.) Measurements showed the cross sectional area of this pit to be 50 square feet, and the calibration by means of known

weights, and therefore columns of water, checked this result so closely that this value was used throughout all the tests. (See Calibration Curve page 36). The Hook gage scale was also checked and found to be correct.

Two pressure gages were used; one for heads of fifty feet or less and the other for higher heads. Both were tested by means of the Crosby Dead Weight Tester and the hands adjusted so as to give accurate readings. Two sets of platform scales were also used, the smaller (as shown in Fig.6,page 29) being used in connection with the Doble tests, where the weight on the scales never exceeded 65 pounds, and the larger scales (see Fig.12 page 32) for the Pelton tests, where the net weight ran above 180 pounds. Both scales were tested and adjusted to read correctly.

Wooden prony brakes having comparatively long arms were available for each motor, but trial showed that the load on the scales was so small that there was likelihood of a large per cent error in reading the weight. For this reason, a rope prony brake having the shortest possible arm was used. As will be seen from the photographs of the apparatus, the rope was fastened to the base of the brake, given a turn around the pulley, and fastened to the threaded hook. The desired tension was accurately obtained by a fine pitch screw.

The gage recorded only the pressure head, while that used for each series of tests was effective head. A fundamental equation of Hydraulics, considering any section where all the readings are taken, is--

$$H = z + h + \frac{v^2}{2g}$$

where H = Effective Head in feet.

Z = Elevation Head or distance between center of section and center of gage = 1.5 ft.

h = Pressure Head as recorded by gage in feet.

$\frac{v^2}{2g}$ = Velocity Head in Feet.

From the following calwulations for the greatest discharge of both the 10 and 100 foot Doble Tests, it will be seen that the maximum velocity head was far below one percent of the effective head and so it could be neglected.

Inside diameter of pipe - 3 1/16 inches.

Inside area of pipe - .614 sq. ft.

Discharge -	10	ft.	Head	- .0805 cu. ft. per sec
	100	"	"	- .273 " " " "
Velocity -	10	"	"	- .131 ft. per sec.
	100	"	"	- .445 " " "
Velocity Head -	10	"	"	- .00027 ft.
	100	"	"	- .00307 "
Percentage -	10	"	"	-..0027 per cent.
	100	"	"	- .00307 " " .

The values for the Pelton were about the same so the velocity head in all cases was disregarded.

The constant elevation head was allowed for by keeping the pressure recorded by the gage 1.5 feet below the desired effective head.

METHOD OF CONDUCTING TESTS.

The manner of carrying out the tests was extremely simple. For the Doble, the needle valve was set in the position to give the desired orifice area. The gate valve was then adjusted to give the required head which was held constant throughout the test by manipulating this valve. Values for the brake load were chosen so as to give about the desired increments of speed, care being taken that the smaller increments were taken in the region of maximum efficiency. This may be seen by reference to any of the effeciency curves following. Brake load and speed were recorded for about ten readings in each test, though their number was sometimes varied.

The exact moment at which the water reached a certain level fixed by the hook gage was noted at the beginning and end of each test. This determined the quantity discharged. The initial weight on the scales was found when the motor was stationary and there was no tension on the rope.

Tests were only run when the conditions were such that a constant head could be easily obtained with slight gate valve adjustments. The bearings were kept well oiled and the brake pulley was water cooled. All data was taken in duplicate to reduce possibility of loss.

For heads of over 50 feet, water from the University mains was used, and the higher reading pressure gage employed. Other-wise there was no change in conditions.

Tests on the Pelton were made exactly as above, except a different pair of platform scales was used.

DISCUSSION OF CALCULATIONS AND CURVES.

The following is an explanation of the various items on the data sheets. Tests were numbered from 1 D to 40 D, inclusive, for the Doble Motor, and from 1 P to 20 P, inclusive, for the Pelton Motor, the order being as indicated in the table on page 6.

The date was put down in the order month, day, and year. The effective head and area of orifice were obtained as explained before. The Rise in pit was obtained from the direct readings on the hook gage scale, and the time in seconds calculated from the two readings of the moments at which the water broke over it. The initial weight on scales was obtained as explained before.

The discharge in cubic feet per second was found by multiplying the rise in pit (ft.) by the cross sectional area of the pit (50 sq. ft.) and dividing by the time (sec.). As there was more likelihood of error in obtaining these values than in securing any of the other data, these discharges were all checked. (See curves on pages 37, 38, and 39). With a constant head the discharge, of course, varies as the area of the orifice. This checked with the above mentioned curves. When values differed materially from those read from the curve, it was evident that an error in observation had been made, and so the curve value was used. It is interesting to note that these points not only fall remarkably close to a straight line for a given head, but that the relation between values for the same orifice area and

different heads also checks out very near to the theoretical relation of the square root of the head. This may readily be seen by comparing values from these curves.

The next item on the data sheet, Jet Horse Power, was obtained from the formula

$$\text{Jet H.P.} = \frac{WH}{550} = \frac{62.5QH}{550}$$

where W. = weight of water discharged per second (lb. per sec.)

H = Effective Head (ft.)

Q = Volume of water discharged per second (cu. ft. per sec.)

The items in the first three columns were number of reading; speed, in revolutions per minute (N in the formula used below); and weight on the scales, in pounds. These were experimental values obtained in the Laboratory. In the fourth column is tabulated the net load on the scales, in pounds (W in formula used below.) This is obtained by subtracting the initial weight on the scales from the total recorded weight as given in column three.

The values of brake horse power (B.H.P.) given in column five were obtained from the following formula

$$\text{B.H.P.} = \frac{2\pi RNW}{33000 \times 12} = .0006545\ NW$$

where B.H.P. = Brake horse power

R = Lever arm (in.) = radius of pulley plus 1/2 diameter of rope = 4 + 1/4 = 4.125 inches

N = Speed in R.P.M. (See column two)

W = Net load on scales in pounds (See column four)

Both pulleys had the same radius so that the constant .0006545 remained the same.

The efficiency in per cent (See Column six) was obtained by dividing the brake horse power by the jet horse power and multiplying by 100.

Sample Calculations.

Test 1 D -

$$\text{Discharge} = \frac{.72 \times 50}{1270} = .02833 \text{ cu. ft. per sec.}$$

$$\text{Jet H.P.} = \frac{62.5 \times .02833 \times 10}{550} = .0322$$

Reading No. 1.

$$W = 15.12 - 12.75 = 2.38 \text{ lb.}$$

$$\text{B.H.P.} = .0006545 \times 62 \times 2.38 = .00964$$

$$\text{Efficiency} = \frac{.00964 \times 100}{.0322} = 29.8 \text{ per cent.}$$

The curves were plotted between values of speed (R.P.M.) as abscissa and efficiency (per cent) as ordinates. A smooth curve was drawn thru as many points as possible so as to obtain average values. All curves of the same motor and under the same head were plotted on one page. The kind of points used for the different curves and the order in which they were numbered is shown by the key on pages 10Q-109.

DISCUSSION OF DATA.

In spite of all precautions slight experimental errors crept in. These were first noticeable when the curves were plotted between the revolutions per minute and the efficiencies. A large number of the points do not lie exactly upon the curves but are scattered upon either side. As explained before smooth curves were drawn thru as many experimental points as possible and were averaged thru the remaining points taking special care that the curves made no radical divergence in shape from the characteristic curve of the tangential water wheel.

In order to check farther the experimental error, a surface was plotted between the variables orifice area, motor efficiency, and effective head. This surface as was first plotted for the Doble 12-inch motor, is shown on page 115. The elements shown here are smooth curves but when the perpendicular elements were drawn in these were found to be somewhat jagged. These irregular curves were plotted upon a separate sheet and all irregularities were smoothed out. Another set of curves were then plotted between efficiency and orifice area by reading points from the above mentioned smoothed curves and the irregularities again removed in a similar manner. After plotting back and forth three times in this way, another surface was laid off which is shown on page 116. The surface for the Pelton 18-inch motor was obtained in a similar manner and only the "faired" surface is shown. (See page 118.)

The blue lines extending from the surface are merely imaginary lines for which no experimental data was obtained. The dotted curved lines represent those elements which would not be seen if the solid actually existed. Given the effective head and orifice area, the maximum efficiency of the motor may be found in the following manner. From the intersection of the head and area coordinates, draw a perpendicular to the XY plane until it intersects the surface. The length of this perpendicular gives the highest efficiency directly in per cent when laid off to the scale on the Z axis. For example with a 60 ft. head and .4 sq. in. orifice area, the intersection is "a" (See page 116) and the perpendicular is "ab" which when measured along the Z axis gives 66.5 percent.

CONCLUSIONS.

From the surface of the Doble 12-inch motor, shown on page 116, it is evident that the crest of maximum efficiencies travels from right to left as the effective head increases. Points on the crest of this wave were projected upon the X-Y plane and it was found that they lay practically upon a straight line. The equation of this line was determined and found to be:-

$$Y + 200X = 110$$

where Y = effective head (ft.)

X = area of orifice (sq. in.)

Knowing the available effective head, the area of orifice to be used for maximum efficiency may be easily found by substituting in the above equation the head for Y and solving for X. It is believed however, that this equation holds only within the limits of these tests. It is probable that as the head increases further than 60 ft., the line would commence to curve and would finally tend to become tangent to the Y or head axis.

The projected points of maximum efficiencies for the Doble motor have been compiled in the following table.

Effective Head (ft.)	Area of Orifice (sq. in.)	Efficiency (Per cent)
10	.5	73.5
20	.44	78.5
30	.41	81.5
40	.34	80.5
50	.3	79.5
60	.25	78.2
80	.225	73.5
100	.15	56.5

From this table, it is apparent that the Doble motor as installed in the University of Illinois Hydraulic Laboratory is most efficient when working under a 30 ft. head with an orifice area of .41 sq. in. It would also be economical to operate this wheel for heads ranging from 20 to 60 feet with the respective areas as above tabulated.

The low efficiencies obtained when under the higher heads, were due partly to the outlet of the wheel case being not large enough to prevent the tail water rising to the buckets. They were also due to the buckets being too small for the large discharge.

The crest of the surface showing the results of tests made upon the Pelton 18-inch motor page 118, is not so pronounced as that of the Doble motor, the surface being more flat. The crest is however perceptible traveling in directions from

a to b as the head increases.

The maximum efficiency obtained in the tests of the Pelton motor was 68.5 per cent when working under a head of 80 ft. and with an orifice area of .601 sq. in. (diameter = 7/8). This value is low in comparison with the values obtained in the Doble motor tests and with the values usual for impulse wheels in general.

It is possible that the maximum efficiency of the Pelton 18-inch motor would occur at a higher head than those used in these tests. With such a few number of elements as were obtained for the surface shown on page 118 it would be impossible to prove conclusively that the maximum efficiency of the motor had been obtained. It would also be impracticable to deduce an expression from this surface, for obtaining the maximum efficiencies for the various heads.

The low effeciency found for the Pelton motor may be accounted for in the following manner. The buckets are cast integral with the web of the wheel and are made of such form as to be easily molded. In as much as the wheel has been in use for some years, the cast iron buckets have become rusty and no longer present a smooth surface to the action of the water. An appreciable amount of the energy of the water is therefore used up by friction in the buckets proper. If the bucket surfaces were polished, it would be expected that the efficiency would rise to at least 80 per cent. If it did not, a change in the design of the buckets would be advocated.

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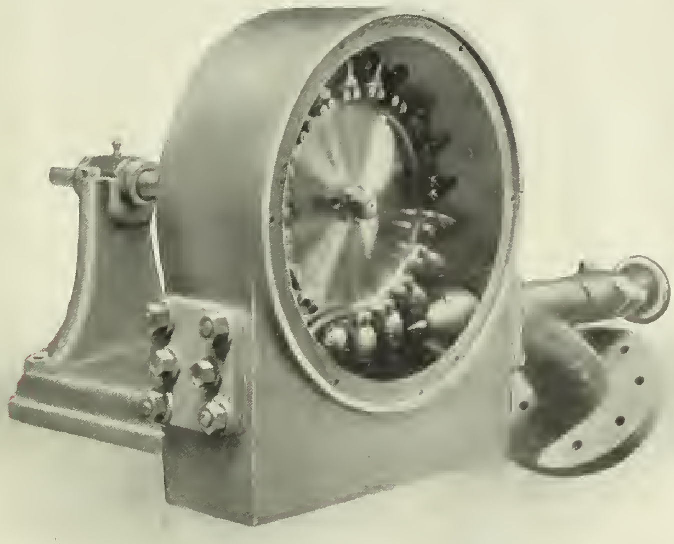
Photographs and Cuts

Cuts from Doble and Pelton Catalogues.

LABORATORY WATER MOTOR

Fig ~~12~~ shows a 12-inch Doble Water Motor designed especially for laboratory use, which we build for universities and technical colleges. This small machine is self-contained, and has the shaft extended far enough to carry a pulley or prony brake. The motor is provided with a Doble Needle Regulating Nozzle for hand



~~Fig. 12~~.

LABORATORY WATER MOTOR FOR TECHNICAL COLLEGES

control, so that the jet of water may be varied to give the desired regulation in speed. The housing has plate-glass sides in order that the students may easily observe the water acting on, and discharging from, the buckets.

These little machines embody the best workmanship that can be turned out, and are designed and finished exactly upon the same lines as our largest machines, the buckets being formed of independent gun-metal castings, ground and polished on the hydraulic surfaces, and bolted to the wheel disc, each by two body-bound bolts fitted into reamed holes.

FIG. 1

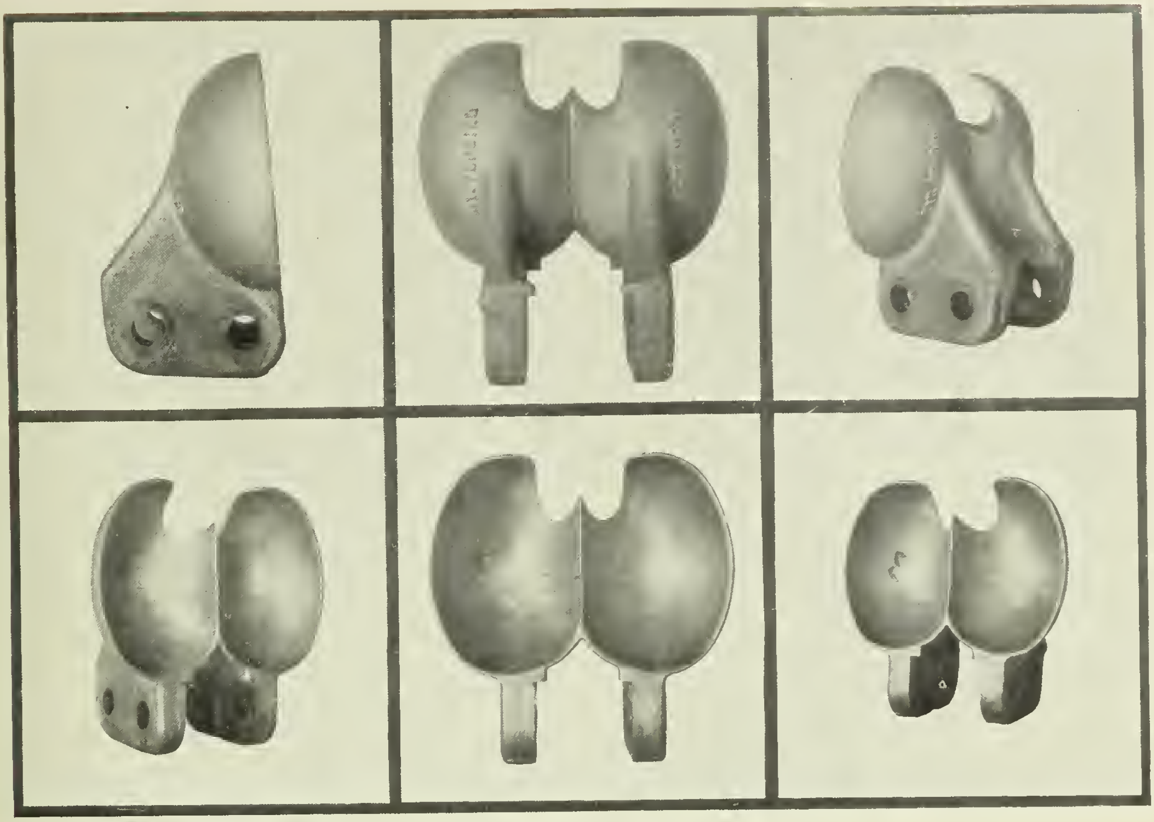
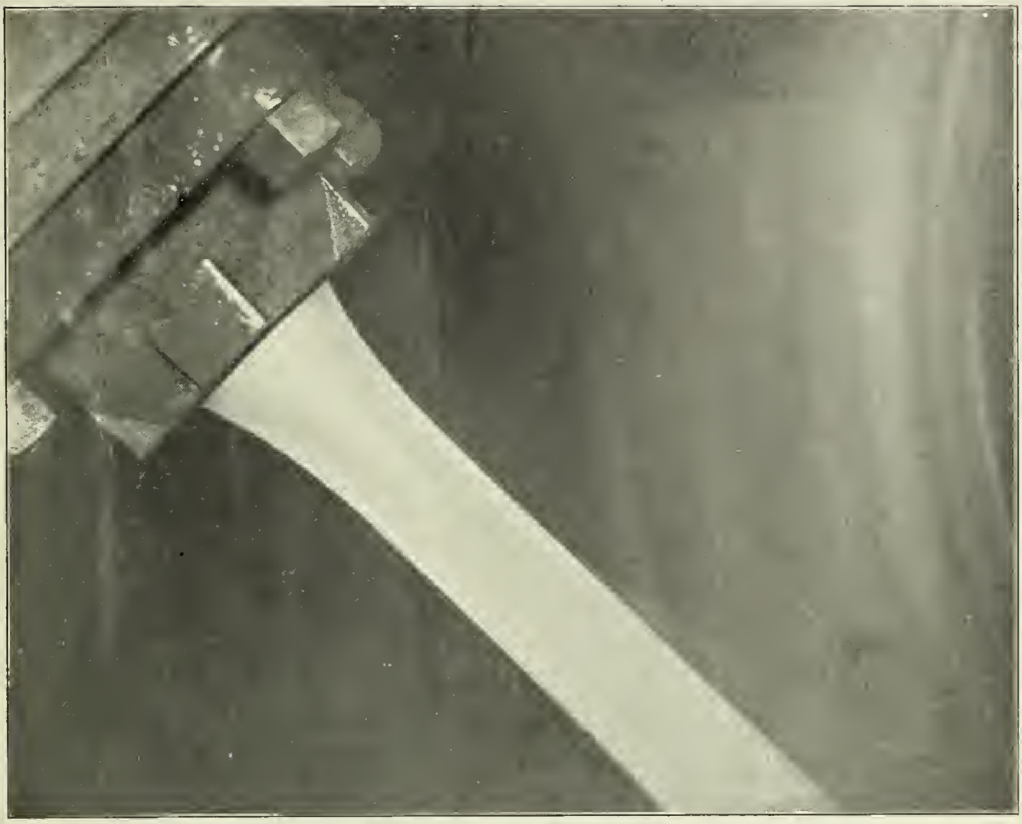


FIG. 2

FIG. 3

DOBLE ELLIPSOIDAL BUCKET



JET OF WATER FROM DOBLE NEEDLE REGULATING NOZZLE

FIG. 4

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Tangential Wheel with Pelton Buckets

FIG. 5

Fig. 6 Rope Prony Brake and Scales

Fig. 7 Measuring Pit E

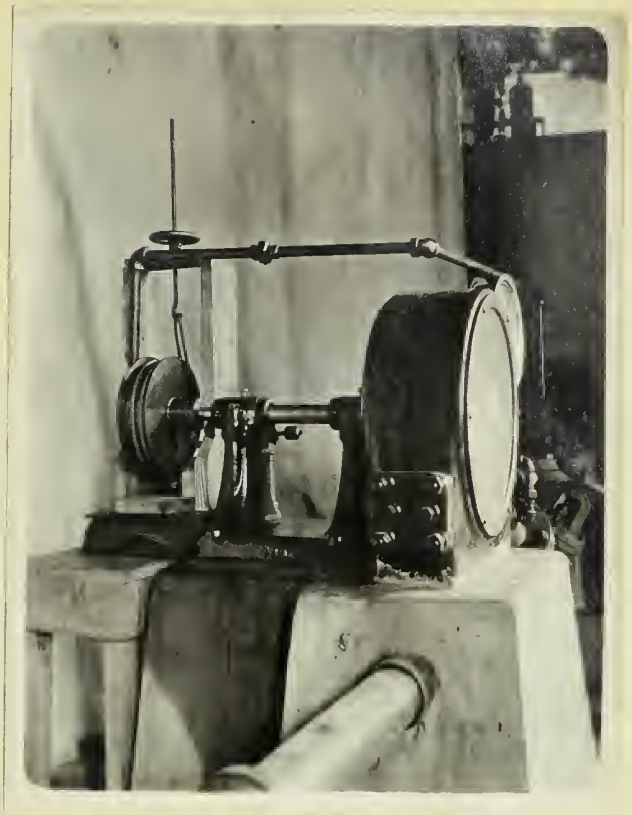


Fig. 8 Doble 12-inch Motor

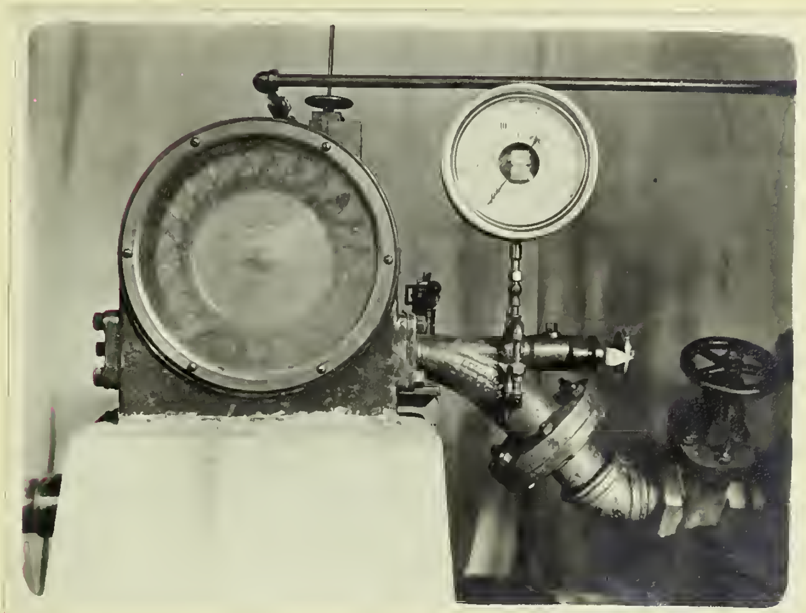


Fig. 9 Doble 12-inch Motor

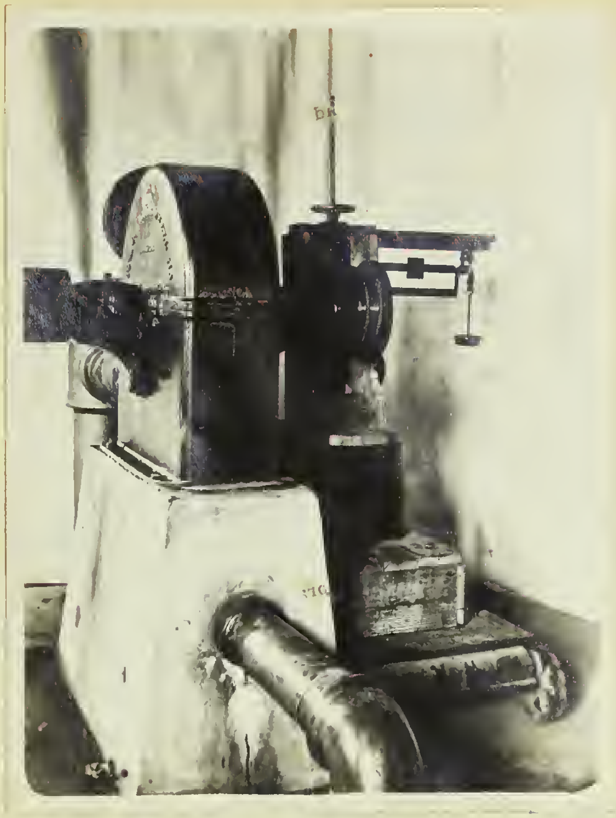


FIG. 10 PELTON 18-INCH MOTOR

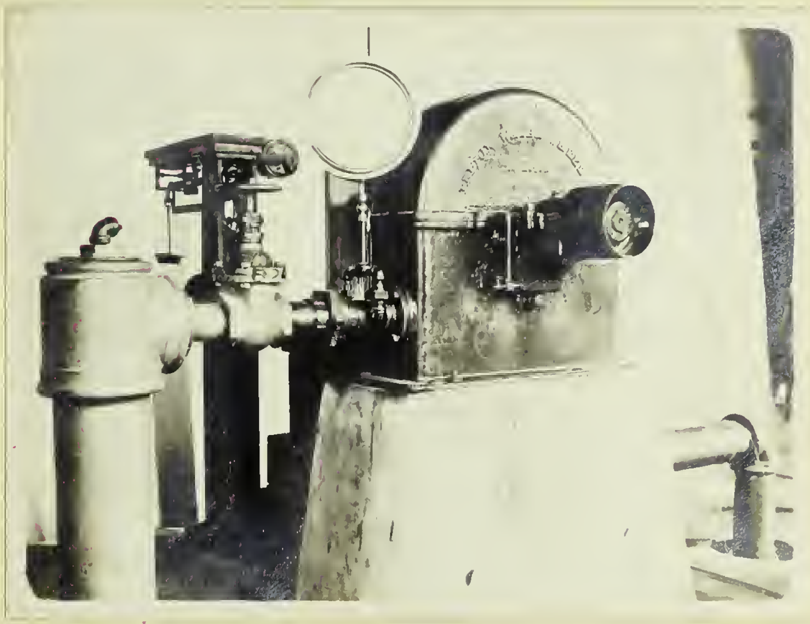


FIG. 11 PELTON 18-INCH MOTOR

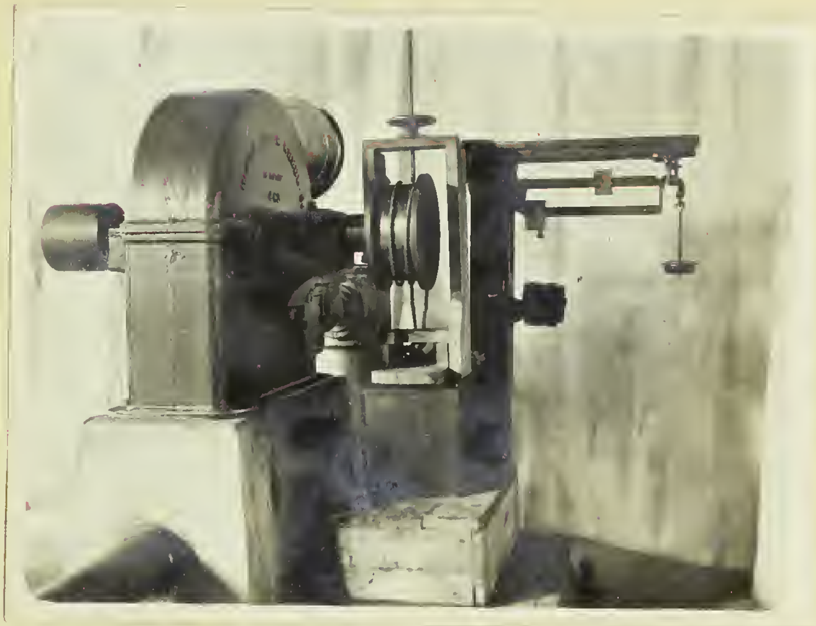
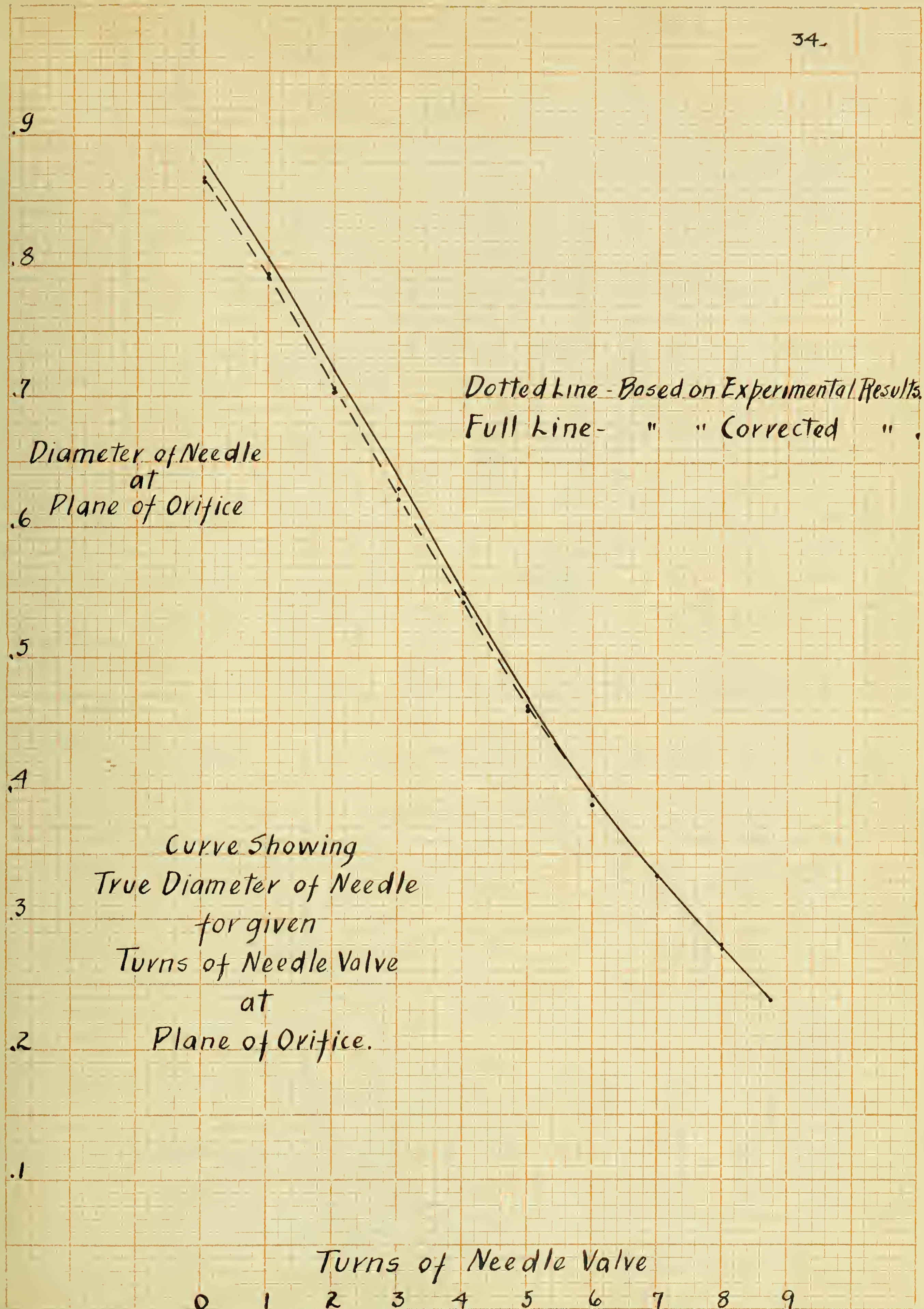
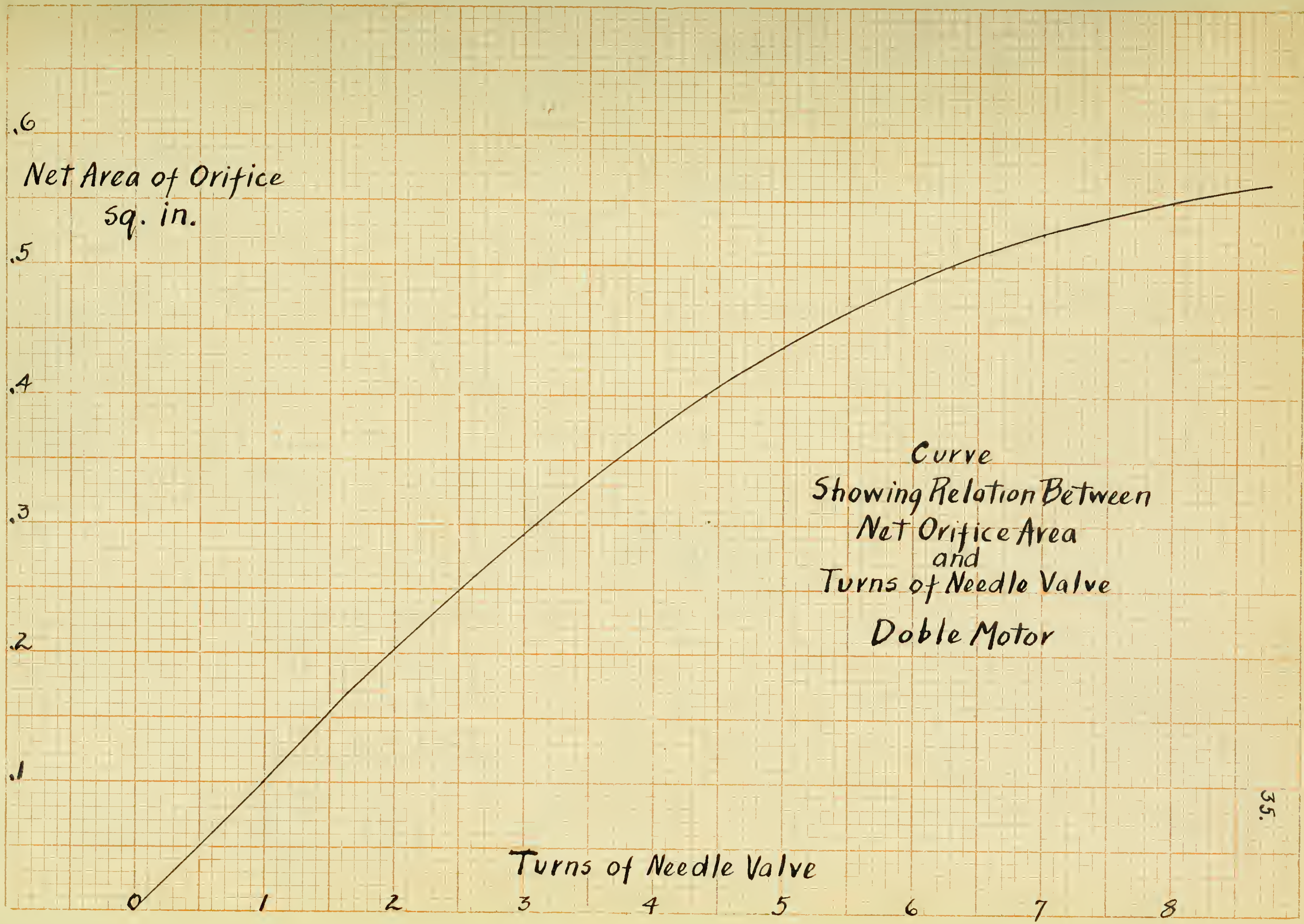


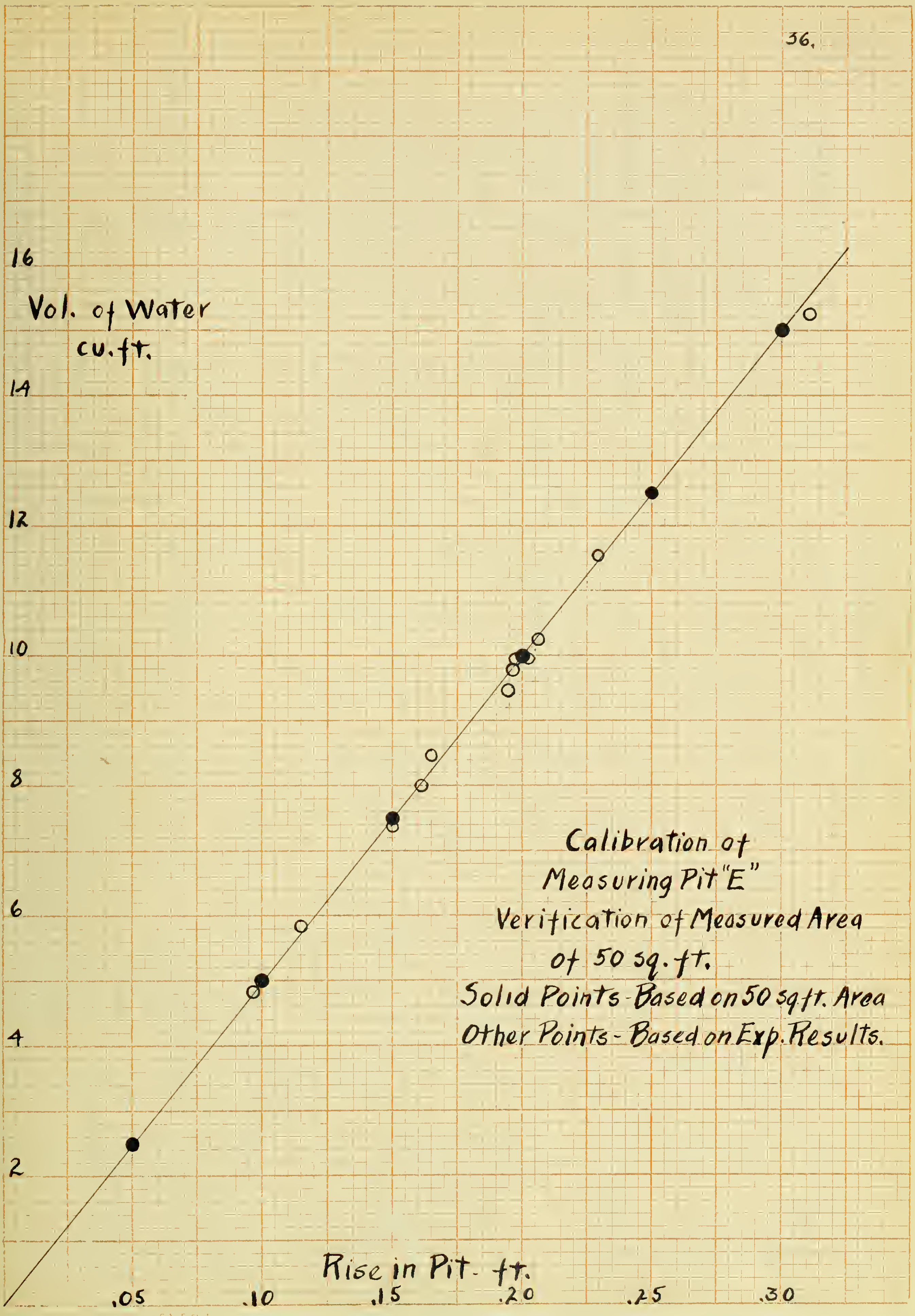
FIG. 12 PELTON 18-INCH MOTOR

No. of Turns.	Diameter of Needle at Plane of Orifice-inches.			Area of Needle sq.in.	Net Area of Orifice sq.in.
	Trial-1.	Trial 2.	From Curve		
0	.865	.868	.882	.611	0
1	.794	.792	.807	.511	.100
2	.704	.704	.720	.407	.204
3	.630	.621	.638	.320	.291
4	.550	.544	.553	.240	.371
5	.460	.462	.470	.173	.438
6	.395	.389	.395	.123	.488
7	.334	.334	.330	.086	.525
8	.278	.280	.278	.061	.550
8.75	.239	.239	.239	.045	.565

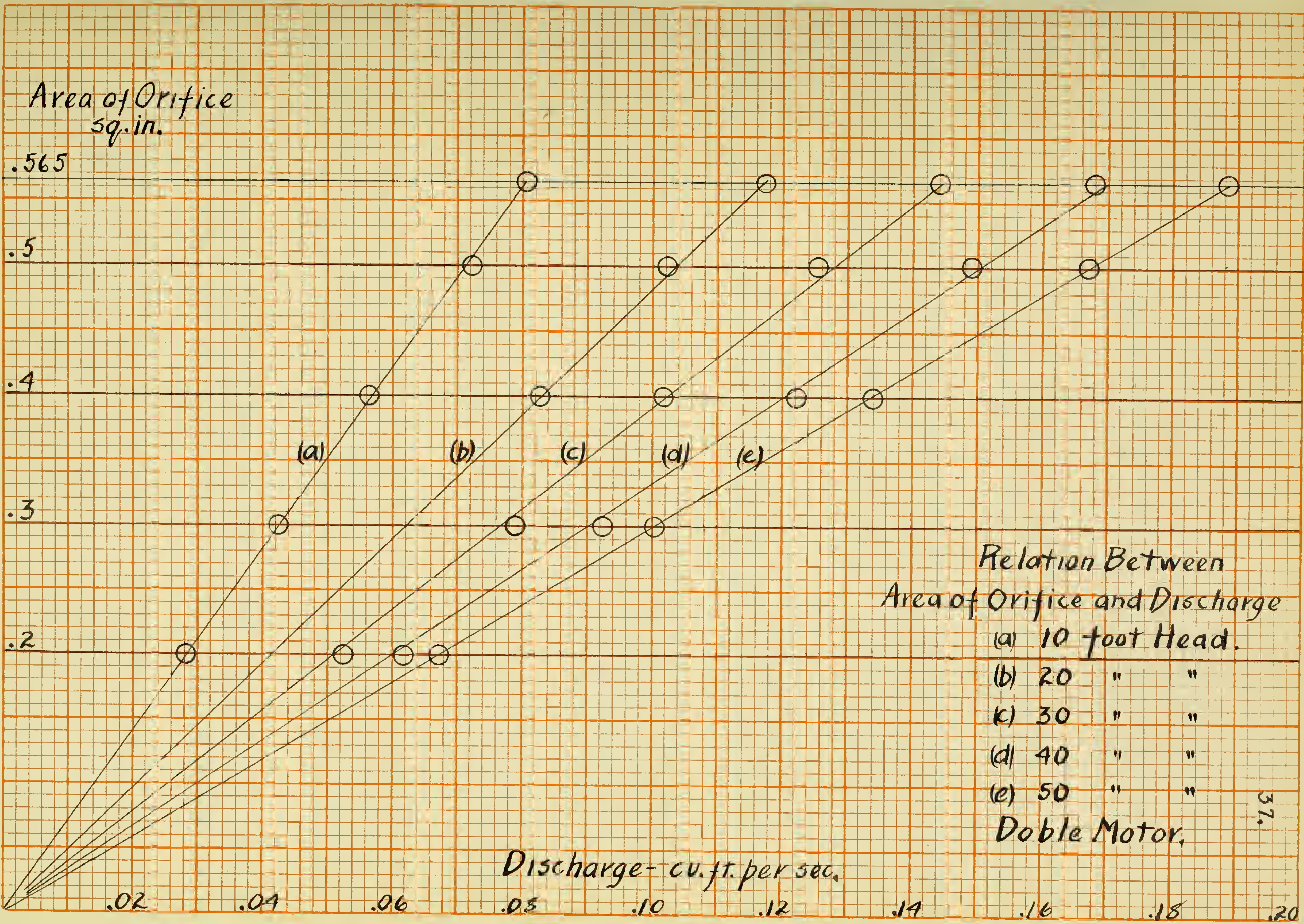
Net Orifice Areas Used. sq.in	Corresponding Valve Turns No.
.2	1.97
.3	3.10
.4	4.40
.5	6.30
.565	8.75


.9
.8
.7
.6
.5
.4
.3
.2
.1
Diameter of Needle at Plane of Orifice
Dotted Line - Based on Experimental Results.
Full Line - " " Corrected " .
Curve Showing True Diameter of Needle for given Turns of Needle Valve at Plane of Orifice.
Turns of Needle Valve
0 1 2 3 4 5 6 7 8 9

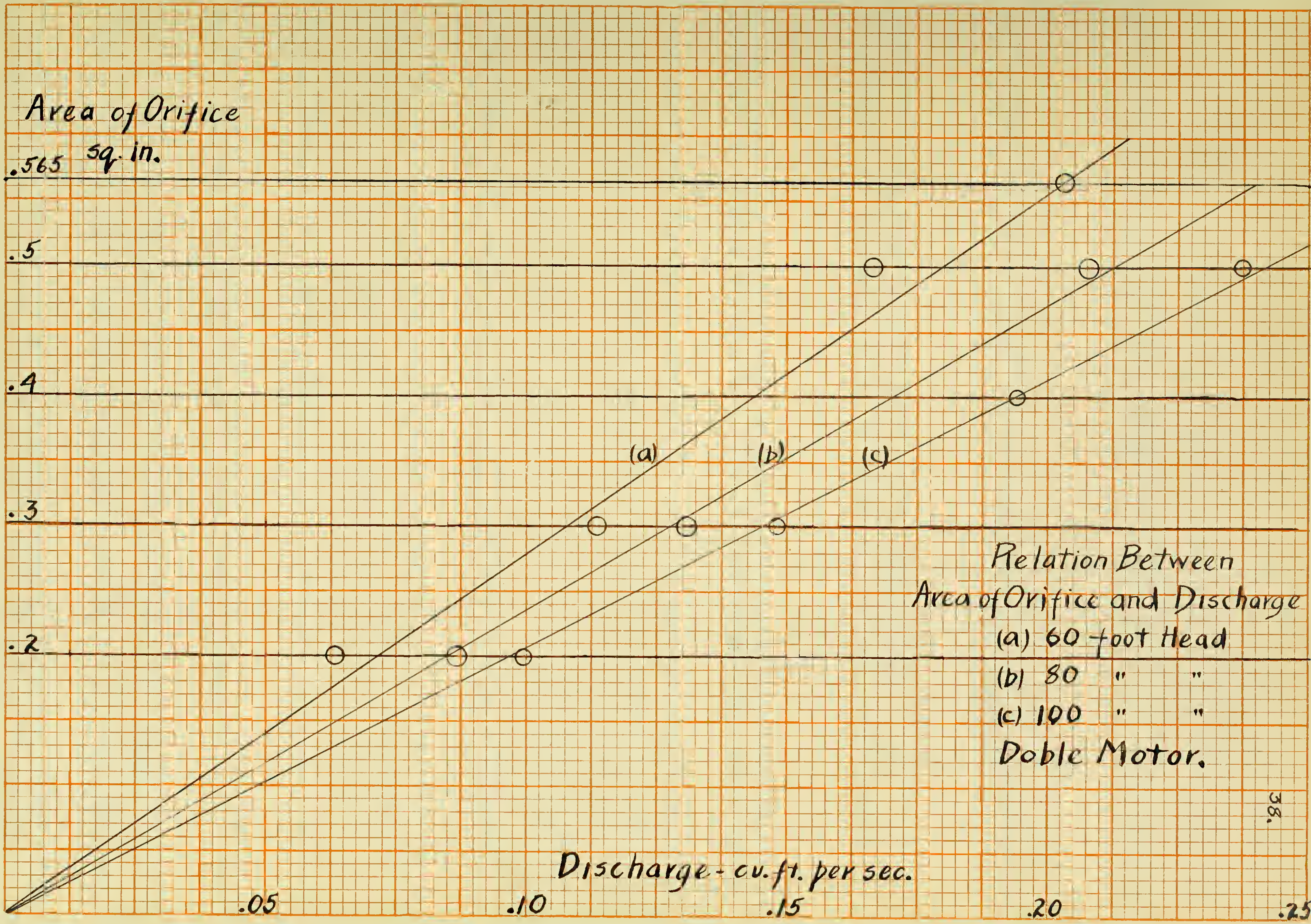

Curve
Showing Relation Between
Net Orifice Area
and
Turns of Needle Valve
Doble Motor
Net Area of Orifice
sq. in.
.6
.5
.4
.3
.2
.1
Turns of Needle Valve
0
1
2
3
4
5
6
7
8

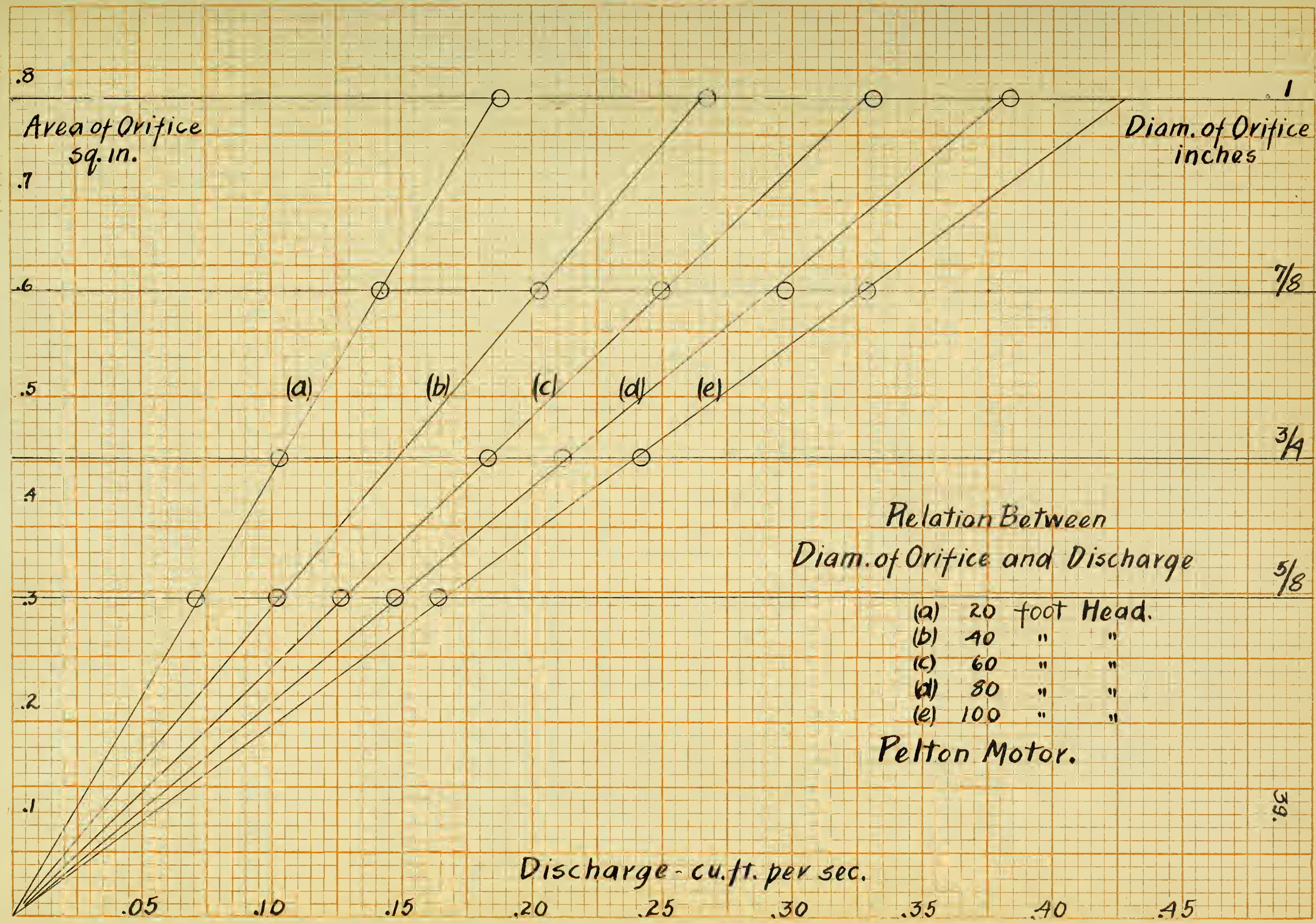


16
Vol. of Water cu. ft.
14
12
10
8
6
4
2
Rise in Pit - ft.
.05
.10
.15
.20
.25
.30
Calibration of Measuring Pit "E"
Verification of Measured Area of 50 sq. ft.
Solid Points - Based on 50 sq. ft. Area
Other Points - Based on Exp. Results.



Area of Orifice
sq. in.
.565
.5
.4
.3
.2
(a)
(b)
(c)
(d)
(e)
Relation Between
Area of Orifice and Discharge
(a) 10 foot Head.
(b) 20 " "
(c) 30 " "
(d) 40 " "
(e) 50 " "
Doble Motor.
37.
Discharge - cu. ft. per sec.
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20


Area of Orifice
sq. in.
.565
.5
.4
.3
.2
(a)
(b)
(c)
Relation Between
Area of Orifice and Discharge
(a) 60 foot Head
(b) 80 " "
(c) 100 " "
Doble Motor.
Discharge - cu. ft. per sec.
.05
.10
.15
.20
.25



Area of Orifice sq. in.
Diam. of Orifice inches
.8
.7
.6
.5
.4
.3
.2
.1
1
7/8
3/4
5/8
(a)
(b)
(c)
(d)
(e)
Relation Between
Diam. of Orifice and Discharge
(a) 20 foot Head.
(b) 40 " "
(c) 60 " "
(d) 80 " "
(e) 100 " "
Pelton Motor.
39.
Discharge - cu. ft. per sec.
.05
.10
.15
.20
.25
.30
.35
.40
.45

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 10 Date: 3/12/10

Effective Head (ft.): 10 Area of Orifice (sq. in.) .2

Rise in Pit (ft.): 3.46-2.74 = .72 Initial Weight on Scales (lb.): 12.75

Time (sec.): 1270 Discharge (cu. ft. per sec.): .02833

Jet H. P.: .0322

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	62	15.12	2.38	.00964	29.8
2	114	14.5	1.75	.01305	40.5
3	162	14.0	1.25	.01323	41.2
4	210	13.5	.75	.01025	31.8
5	245	13.0	.25	.00400	12.4

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 2 D

Date: 3/12/10

Effective Head (ft.): 10

Area of Orifice (sq. in.) .3

Rise in Pit (ft.): 3.62 - 2.61 = 1.01

Initial Weight on Scales (lb.): 12.75

Time (sec.): 1190

Discharge (cu. ft. per sec.): .04245

Jet H. P.: .0482

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	45	16.5	3.75	.01103	22.9
2	86	16.0	3.25	.01829	37.9
3	119	15.5	2.75	.02140	44.4
4	160	15.0	2.25	.02357	48.8
5	186	14.5	1.75	.02130	44.2
6	218	14.0	1.25	.01783	37.0
7	266	13.5	.75	.01305	27.0
8	286	13.0	.25	.00468	9.7

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 3 D

Date: 3/12/10

Effective Head (ft.): 10

Area of Orifice (sq. in.) .4

Rise in Pit (ft.): 3.59-2.12=1.47

Initial Weight on Scales (lb.): 12.75

Time (sec.): 1305

Discharge (cu. ft. per sec.): .0564

Jet H. P.: .0641

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	71	17.5	4.75	.02208	34.4
2	102	17.	4.25	.02840	44.3
3	135	16.5	3.75	.03315	51.6
4	160	16.	3.25	.03402	53.0
5	186	15.5	2.75	.03345	52.1
6	216	15.	2.25	.03180	49.6
7	241	14.5	1.75	.02760	43.0
8	258	14.	1.25	.02120	33.0
9	297	13.5	.75	.01460	22.8
10	312	13.	.25	.00511	7.9

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 4 D Date: 3/12/10

Effective Head (ft.): 10 Area of Orifice (sq. in.) .5

Rise in Pit (ft.): 3.52 − 1.69 = 1.83 Initial Weight on Scales (lb.): 12.75

Time (sec.): 1270 Discharge (cu. ft. per sec.): .07203

Jet H. P.: .08195

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	55	19.	6.25	.02252	27.45
2	86	18.5	5.75	.0324	39.55
3	120	18.	5.25	.0412	50.3
4	138	17.5	4.75	.0429	52.4
5	166	17.	4.25	.0462	56.4
6	187	16.5	3.75	.04595	56.6
7	214	16.	3.25	.0455	55.5
8	231	15.5	2.75	.0416	50.8
9	239	15.	2.25	.0352	43.0
10	260	14.5	1.75	.02975	36.3
11	278	14.	1.25	.02275	27.7
12	306	13.5	.75	.01501	18.35
13	312	13.	.25	.00511	6.24

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 5 D

Date: 3/19/10

Effective Head (ft.): 10

Area of Orifice (sq. in.) .565

Rise in Pit (ft.): 4.63 - 2.70 = 1.93

Initial Weight on Scales (lb.): 12.35

Time (sec.): 1300

Discharge (cu. ft. per sec.): .0805

Jet H. P.: .0915

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	118	18	5.65	.0436	47.6
2	144	17.5	5.15	.0485	53.0
3	150	17.25	4.90	.0481	52.6
4	161	17.	4.65	.0490	53.5
5	173	16.75	4.40	.0498	54.5
6	180	16.5	4.15	.0488	53.4
7	181	16.25	3.90	.0462	50.5
8	202	16.	3.65	.0482	52.7
9	240	15	2.65	.0416	45.5
10	318	13	.65	.0135	14.7

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 6 D

Date: 3/19/10

Effective Head (ft.): 20

Area of Orifice (sq. in.) .2

Rise in Pit (ft.): Discharge

Initial Weight on Scales (lb.): 12.35

Time (sec.): read from curve

Discharge (cu. ft. per sec.): .0415

Jet H. P.: .0944

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	115	18	5.65	.0425	45.0
2	190	17	4.65	.0578	61.2
3	234	16.5	4.15	.0635	67.2
4	246	16.25	3.90	.0628	66.5
5	262	16.	3.65	.0626	66.4
6	266	15.75	3.40	.0592	62.7
7	308	15.5	3.15	.0635	67.2
8	326	15.	2.65	.0566	60.0
9	404	14.	1.65	.0433	46.2
10	478	13.	.65	.0204	21.6

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 7 D Date: 3/19/10

Effective Head (ft.): 20 Area of Orifice (sq. in.) .3

Rise in Pit (ft.): Discharge Initial Weight on Scales (lb.): 12.35

Time (sec.): read from curve Discharge (cu. ft. per sec.): .062

Jet H. P.: .1408

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	80	21.	8.65	.0453	32.2
2	212	19.	6.65	.0923	65.6
3	218	18.75	6.40	.0913	64.9
4	242	18.5	6.15	.0974	69.2
5	268	18.25	5.90	.1032	73.4
6	290	18.	5.65	.1072	76.3
7	296	17.75	5.40	.1048	74.4
8	290	17.5	5.15	.0977	69.5
9	309	17.25	4.90	.0991	70.5
10	378	16.	3.65	.0903	64.2
11	494	13.	.65	.0210	14.9

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 8 D

Date: 3/19/10

Effective Head (ft.): 20

Area of Orifice (sq. in.) .4

Rise in Pit (ft.): 4.67 − 2.35 = 2.32

Initial Weight on Scales (lb.): 12.35

Time (sec.): 1400

Discharge (cu. ft. per sec.): .0829

Jet H. P.: .1882

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	71	24	11.65	.0541	28.7
2	197	21.5	9.15	.1180	62.7
3	246	20.5	8.15	.1311	69.6
4	260	20.25	7.90	.1345	71.4
5	280	20.00	7.65	.1400	74.4
6	289	19.75	7.40	.1400	74.4
7	294	19.50	7.16	.1379	73.2
8	300	19.25	6.90	.1359	72.1
9	314	19.00	6.65	.1369	72.6
10	380	17.00	4.65	.1157	61.4
11	494	13.00	.65	.0210	11.1

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 9 D Date: 3/19/10

Effective Head (ft.): 20 Area of Orifice (sq. in.) .5

Rise in Pit (ft.): 4.74 − 1.77 = 2.97 Initial Weight on Scales (lb.): 12.35

Time (sec.): 1450 Discharge (cu. ft. per sec.): .1022

Jet H. P.: .2324

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	74	26	13.65	.0706	30.4
2	164	24	11.65	.1250	53.7
3	236	22.5	10.15	.1567	67.4
4	252	22.25	9.90	.1631	70.2
5	265	22.	9.65	.1671	71.9
6	280	21.75	9.40	.1720	73.9
7	280	21.5	9.15	.1678	72.0
8	294	21.25	8.90	.1711	73.6
9	309	20.75	8.40	.1699	72.9
10	424	17.	4.65	.1289	55.4
11	516	13.	.65	.0220	9.4

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 10 D

Date: 3/19/10

Effective Head (ft.): 20

Area of Orifice (sq. in.) .565

Rise in Pit (ft.): 4.53-1.25=3.28

Initial Weight on Scales (lb.): 12.35

Time (sec.): 1395

Discharge (cu. ft. per sec.): .1175

Jet H. P.: .267

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	108	27.	14.65	.1035	38.8
2	157	26	13.65	.1408	52.6
3	234	24	11.65	.1784	66.8
4	244	23.75	11.4	.1820	68.1
5	248	23.5	11.15	.1810	67.7
6	260	23.25	10.9	.1855	69.4
7	260	23	10.65	.1815	68.0
8	274	22.75	10.4	.1865	69.8
9	290	22	9.65	.1830	68.5
10	394	18	5.65	.1455	54.4
11	542	13	.65	.0230	8.6

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 11 D

Date: 3/31/10

Effective Head (ft.): 30

Area of Orifice (sq. in.) .2

Rise in Pit (ft.): 3.43 - 1.60 = 1.83

Initial Weight on Scales (lb.): 12.1

Time (sec.): 1743

Discharge (cu. ft. per sec.): .0525

Jet H. P.: .179

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	62	21.5	9.4	.0382	21.3
2	164	20.	7.9	.0846	47.3
3	246	19.	6.9	.1111	62.1
4	278	18.5	6.4	.1163	65.0
5	298	18.25	6.15	.1200	67.0
6	312	18	5.9	.1202	67.2
7	318	17.75	5.65	.1173	65.6
8	344	17.5	5.4	.1217	68.0
9	378	17.	4.9	.1210	67.6
10	430	16.	3.9	.1095	61.2
11	488	15.	2.9	.0926	51.8
12	558	13.5	1.4	.0512	28.6
13	588	13.	.9	.0347	19.4

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 12 D

Date: 3/31/10

Effective Head (ft.): 30

Area of Orifice (sq. in.) .3

Rise in Pit (ft.): 3.91 - 1.50 = 2.41

Initial Weight on Scales (lb.): 12.1

Time (sec.): 1526

Discharge (cu. ft. per sec.): .079

Jet H. P.: .2692

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	88	26	13.9	.0800	29.7
2	214	24	11.9	.1669	62.0
3	266	23	10.9	.1899	70.5
4	312	22	9.9	.2020	75.1
5	334	21	8.9	.1943	72.1
6	390	20	7.9	.2017	74.9
7	418	19	6.9	.1890	70.2
8	460	18	5.9	.1777	66.0
9	492	17	4.9	.1578	58.6
10	512	16	3.9	.1305	48.5
11	552	15	2.9	.1050	39.0
12	600	13.5	1.4	.0550	20.4
13	642	13	.9	.0378	14.0

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR.

A. O. SPIERLING

No. of test: 13 D

Date: 3/31/10

Effective Head (ft.): 30

Area of Orifice (sq. in.) .4

Rise in Pit (ft.): 3.88 − 0.99 = 2.89

Initial Weight on Scales (lb.): 12.1

Time (sec.): 1418

Discharge (cu. ft. per sec.): .1019

Jet H. P.: .3475

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	96	30	17.9	.1125	32.3
2	193	28	15.9	.2010	57.9
3	282	26	13.9	.2570	74.0
4	316	25	12.9	.2670	76.8
5	348	24	11.9	.2707	77.9
6	376	23	10.9	.2681	77.1
7	410	22	9.9	.2655	76.4
8	464	20	7.9	.2395	68.9
9	520	18	5.9	.2008	57.8
10	558	16	3.9	.1425	41.0
11	640	14	1.9	.0796	22.9
12	650	13	.9	.0383	11.0

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 14 D Date: 3/31/10

Effective Head (ft.): 30 Area of Orifice (sq. in.) .5

Rise in Pit (ft.): 4.2-1.7=2.5 Initial Weight on Scales (lb.): 12.1

Time (sec.): 995 Discharge (cu. ft. per sec.): .1255

Jet H. P.: .428

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	94	34	21.9	.1349	31.5
2	152	32	19.9	.1980	46.3
3	276	29	16.9	.3050	71.2
4	328	27	14.9	.3200	74.7
5	354	26	13.9	.3220	75.2
6	378	25	12.9	.3192	74.5
7	422	23	10.9	.3019	70.4
8	498	20	7.9	.2575	60.1
9	570	16	3.9	.1453	33.9
10	648	13	.9	.0382	8.9

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 15 D

Date: 3/31/10

Effective Head (ft.): 30

Area of Orifice (sq. in.) .565

Rise in Pit (ft.): 3.64 − 0.86 = 2.78

Initial Weight on Scales (lb.): 12.1

Time (sec.): 965

Discharge (cu. ft. per sec.): .144

Jet H. P.: .492

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	178	35	22.9	.1918	39.0
2	222	32	19.9	.2895	58.8
3	284	30	17.9	.3325	67.5
4	314	29	16.9	.3478	70.6
5	340	28	15.9	.3540	71.9
6	386	26	13.9	.3518	71.5
7	432	23	10.9	.3080	62.6
8	478	20	7.9	.2472	50.2
9	520	16	3.9	.1327	26.9
10	575	13	.9	.0338	6.9

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR.

A. O. SPIERLING

No. of test: 16 D

Date: 4/2/10

Effective Head (ft.): 40

Area of Orifice (sq. in.) .2

Rise in Pit (ft.): 3.69-2.15=1.54

Initial Weight on Scales (lb.): 12.2

Time (sec.): 12.46

Discharge (cu. ft. per sec.): .618

Jet H. P.: .281

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	102	25	12.8	.0854	30.4
2	164	24	11.8	.1268	45.1
3	290	22	9.8	.1859	66.0
4	346	21	8.8	.1992	70.8
5	374	20.5	8.3	.2028	72.2
6	390	20	7.8	.1990	70.7
7	422	19.5	7.3	.2015	71.6
8	442	19.	6.8	.1970	70.0
9	540	17	4.8	.1695	60.3
10	620	15	2.8	.1136	40.4
11	706	13	.8	.0370	13.2

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR.

A. O. SPIERLING

No. of test: 17 D

Date: 4/2/10

Effective Head (ft.): 40

Area of Orifice (sq. in.) .3

Rise in Pit (ft.): 3.80-1.28=2.52

Initial Weight on Scales (lb.): 12.2

Time (sec.): 136.5

Discharge (cu. ft. per sec.): .924

Jet H. P.: 4.20

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	100	31	18.8	.1230	29.3
2	226	28	15.8	.2335	55.6
3	280	27	14.8	.2715	64.6
4	312	26	13.8	.2815	67.2
5	350	25	12.8	.2930	69.8
6	400	24	11.8	.3090	73.5
7	426	23	10.8	.3018	71.8
8	504	21	8.8	.2900	69.0
9	620	17	4.8	.1947	46.0
10	676	15	2.8	.1240	29.5
11	720	13	.8	.0377	9.0

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 18 D

Date: 4/2/10

Effective Head (ft.): 40

Area of Orifice (sq. in.) .4

Rise in Pit (ft.): 3.14 − .75 = 2.39

Initial Weight on Scales (lb.): 12.2

Time (sec.): 976

Discharge (cu. ft. per sec.): .1222

Jet H. P.: .556

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	160	35	22.8	.2388	43.0
2	308	31	18.8	.3790	68.2
3	366	29	16.8	.4025	72.4
4	400	28	15.8	.4140	74.5
5	424	27	14.8	.4115	74.0
6	446	26	13.8	.4030	72.5
7	512	24	11.8	.3960	71.2
8	580	20	7.8	.2957	53.2
9	680	16	3.8	.1690	30.4
10	760	13	.8	.0398	7.2

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 19 D

Date: 4/2/10

Effective Head (ft.): 40

Area of Orifice (sq. in.): .5

Rise in Pit (ft.): 3.70 - .74 = 2.96

Initial Weight on Scales (lb.): 12.2

Time (sec.): 99.2

Discharge (cu. ft. per sec.): .1491

Jet H. P.: .678

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	106	41	28.8	.2322	34.3
2	170	36	23.8	.2645	39.0
3	296	34	21.8	.4220	62.5
4	340	33	20.8	.4625	68.2
5	360	32	19.8	.4670	68.8
6	430	30	17.8	.5010	73.8
7	464	26	13.8	.4185	61.7
8	492	21	8.8	.2835	41.8
9	530	17	4.8	.1664	24.5
10	580	13	.8	.0304	4.5

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 20 D

Date: 4/2/10

Effective Head (ft.): 40

Area of Orifice (sq. in.) .565

Rise in Pit (ft.): 3.71 − .81 = 2.90

Initial Weight on Scales (lb.): 12.2

Time (sec.): 863

Discharge (cu. ft. per sec.): .1680

Jet H. P.: .764

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	126	43	30.8	.2540	33.2
2	220	39	26.8	.3860	50.5
3	234	38	25.8	.3955	51.7
4	238	37	24.8	.3860	50.5
5	260	35	22.8	.3880	50.8
6	290	33	20.8	.3950	51.6
7	364	30	17.8	.4240	55.5
8	428	26	13.8	.3870	50.6
9	460	20	7.8	.2348	30.7
10	500	13	.8	.0262	3.4

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 21D Date: 4/8/10

Effective Head (ft.): 50 Area of Orifice (sq. in.) .2

Rise in Pit (ft.): 4.85-2.35=2.5 Initial Weight on Scales (lb.): 12.2

Time (sec.): 1740 Discharge (cu. ft. per sec.): .0672

Jet H. P.: .382

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	104	28	15.8	.1075	28.1
2	201	26	13.8	.1818	47.5
3	265	25	12.8	.2220	58.1
4	364	24	11.8	.2807	73.5
5	415	23	10.8	.2935	76.8
6	439	22	9.8	.2815	73.6
7	486	21	8.8	.2800	73.3
8	563	20	7.8	.2875	75.3
9	670	17	4.8	.2100	55.0
10	820	13	.8	.043	11.2

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 22 D

Date: 4/8/10

Effective Head (ft.): 50

Area of Orifice (sq. in.) .3

Rise in Pit (ft.): 4.75 - 2.00 = 2.75

Initial Weight on Scales (lb.): 12.2

Time (sec.): 1340

Discharge (cu. ft. per sec.): .1005

Jet H. P.: .571

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	153	35	22.8	.2282	40.0
2	316	31	18.8	.3880	67.9
3	396	29	16.8	.4355	76.3
4	413	28	15.8	.4270	74.7
5	466	27	14.8	.4515	79.0
6	494	26	13.8	.4460	78.1
7	494	25	12.8	.4140	72.5
8	612	21	8.8	.3525	61.8
9	709	17	4.8	.2228	39.0
10	853	13	.8	.0447	7.8

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 23 D Date: 4/8/10

Effective Head (ft.): 50 Area of Orifice (sq. in.) .4

Rise in Pit (ft.): 4.50 - 0.80 = 3.70 Initial Weight on Scales (lb.): 12.2

Time (sec.): 1370 Discharge (cu. ft. per sec.): .1340

Jet H. P.: .761

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	121	43	30.8	.2440	32.1
2	232	39	26.8	.4070	53.5
3	268	38	25.8	.4530	59.5
4	314	37	24.8	.5100	67.0
5	348	36	23.8	.5430	71.4
6	362	35	22.8	.5410	71.0
7	382	34	21.8	.5450	71.6
8	432	32	19.8	.5605	73.6
9	538	28	15.8	.5570	73.1
10	598	22	9.8	.3840	50.5
11	666	17	4.8	.2095	27.5
12	770	13	.8	.0404	5.3

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 24 D

Date: 4/8/10

Effective Head (ft.): 50

Area of Orifice (sq. in.) .5

Rise in Pit (ft.): 4.80 − 0.75 = 4.05

Initial Weight on Scales (lb.): 12.2

Time (sec.): 1220

Discharge (cu. ft. per sec.): .1670

Jet H. P.: .949

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	113	48	35.8	.2650	27.9
2	230	43	30.8	.4640	48.9
3	240	41	28.8	.4525	47.7
4	272	39	26.8	.4770	50.2
5	302	37	24.8	.4900	51.6
6	344	35	22.8	.5140	54.1
7	420	31	18.8	.5160	54.4
8	494	25	12.8	.4140	43.6
9	504	19	6.8	.2245	23.6
10	596	13	.8	.0312	3.3

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 25 D

Date: 4/8/10

Effective Head (ft.): 50

Area of Orifice (sq. in.) .565

Rise in Pit (ft.): 4.55 − 0.63 = 3.92

Initial Weight on Scales (lb.): 12.2

Time (sec.): 1053

Discharge (cu. ft. per sec.): .1885

Jet H. P.: 1.07

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	160	49	36.8	.3855	36.0
2	218	45	32.8	.4680	43.8
3	236	43	30.8	.4760	44.5
4	254	41	28.8	.4790	44.8
5	274	39	26.8	.4815	45.0
6	302	37	24.8	.4905	45.9
7	332	35	22.8	.4950	46.3
8	390	30	17.8	.4545	42.5
9	452	25	12.8	.3790	35.4
10	484	20	7.8	.2475	23.1
11	520	13	.8	.0272	2.5

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 26 D Date: 4-12-10

Effective Head (ft.): 60 Area of Orifice (sq. in.) .2

Rise in Pit (ft.): Discharge Initial Weight on Scales (lb.): 1.00

Time (sec.): read from curve Discharge (cu. ft. per sec.): .072

Jet H. P.: .491

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	78	21	20	.1020	20.8
2	234	18	17	.2602	53.0
3	332	16	15	.3260	66.4
4	406	15	14	.3720	75.7
5	452	14	13	.3850	78.4
6	494	13	12	.3880	79.0
7	550	11	10	.3600	73.3
8	664	8	7	.3035	61.8
9	778	5	4	.2037	41.5
10	894	2	1	.0585	11.9

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 27 D

Date: 4/12/10

Effective Head (ft.): 60

Area of Orifice (sq. in.) .3

Rise in Pit (ft.): Discharge

Initial Weight on Scales (lb.): 1.00

Time (sec.): read from curve

Discharge (cu. ft. per sec.): 1.075

Jet H. P.: .733

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	114	30	29	.2165	29.6
2	252	26	25	.4120	56.3
3	386	23	22	.5555	75.9
4	426	21	20	.5580	76.1
5	511	19	18	.6025	82.2
6	548	17	16	.5740	78.3
7	678	13	12	.5330	72.7
8	738	9	8	.3870	51.5
9	802	5	4	.2100	28.6
10	898	2	1	.0587	8.0

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 28 D

Date: 4/12/10

Effective Head (ft.): 60

Area of Orifice (sq. in.) .4

Rise in Pit (ft.): Discharge

Initial Weight on Scales (lb.): 1.00

Time (sec.): read from curve

Discharge (cu. ft. per sec.): .144

Jet H. P.: .982

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	80	39	38	.1990	20.2
2	260	33	32	.5450	55.5
3	315	29	28	.5770	58.8
4	326	26	25	.5335	54.3
5	486	24	23	.7300	74.4
6	530	22	21	.7290	74.2
7	540	19	18	.6360	64.8
8	564	13	12	.4440	45.2
9	604	8	7	.2765	28.1
10	670	2	1	.0439	4.5

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 29 D

Date: 4/18/10

Effective Head (ft.): 60

Area of Orifice (sq. in.): .5

Rise in Pit (ft.): Discharge

Initial Weight on Scales (lb.): 1.00

Time (sec.): read from curve

Discharge (cu. ft. per sec.): 1.8

Jet H. P.: 1.228

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	112	44	43	.3155	25.6
2	235	37	36	.5540	45.1
3	260	32	31	.5280	43.0
4	354	26	25	.5795	47.2
5	360	24	23	.5415	44.2
6	425	20	19	.5285	43.1
7	480	16	15	.4710	38.4
8	484	12	11	.3483	28.2
9	556	7	6	.2180	17.8
10	598	2	1	.0392	3.2

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 30 D

Date: 4/12/10

Effective Head (ft.): 60

Area of Orifice (sq. in.) .565

Rise in Pit (ft.): 4.25 - .80 = 3.45

Initial Weight on Scales (lb.): 1.00

Time (sec.): 8.47

Discharge (cu. ft. per sec.): 2.036

Jet H. P.: 1.387

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	82	50	49	.2632	19.0
2	120	46	45	.3538	25.5
3	150	44	43	.4220	30.5
4	166	42	41	.4460	32.2
5	224	39	38	.4570	33.0
6	245	36	35	.5610	40.5
7	294	30	29	.5585	40.3
8	414	22	21	.5690	41.1
9	471	14	13	.4010	29.0
10	508	7	6	.1995	14.4
11	566	2	1	.0371	2.7

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING.

No. of test: 31 D Date: 4/14/10

Effective Head (ft.): 80 Area of Orifice (sq. in.) .2

Rise in Pit (ft.): 4.31 - 2.48 = 1.83 Initial Weight on Scales (lb.): 1.00

Time (sec.): 10.48 Discharge (cu. ft. per sec.): .0874

Jet H. P.: .795

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	160	26	25	.2619	32.9
2	284	23	22	.4090	51.4
3	374	21	20	.4900	61.6
4	470	19	18	.5501	69.2
5	550	17	16	.5760	72.5
6	628	15	14	.5760	72.5
7	714	12	11	.5145	64.6
8	814	9	8	.4260	53.6
9	938	5	4	.2455	30.8
10	1008	2	1	.0659	8.3

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 32 D Date: 4/14/10

Effective Head (ft.): 80 Area of Orifice (sq. in.) .3

Rise in Pit (ft.): 3.70 - .81 = 2.89 Initial Weight on Scales (lb.): 1.00

Time (sec.): 110.5 Discharge (cu. ft. per sec.): .1309

Jet H. P.: 1.19

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	180	38	37	.4360	36.7
2	266	35	34	.5920	49.8
3	354	32	31	.7190	60.4
4	450	29	28	.8245	69.2
5	500	27	26	.8500	71.5
6	550	25	24	.8640	72.6
7	694	19	18	.8180	68.8
8	712	12	11	.5130	43.1
9	860	6	5	.2815	23.6
10	906	2	1	.0594	5.0

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR.　　A. O. SPIERLING

No. of test: 33 D　　Date: 4/14/10

Effective Head (ft.): 80　　Area of Orifice (sq. in.) .4

Rise in Pit (ft.): Discharge　　Initial Weight on Scales (lb.): 1.00

Time (sec.): read from curve　　Discharge (cu. ft. per sec.): .170

Jet H. P.: 1.548

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	152	47	46	.4570	29.6
2	256	42	41	.6870	44.5
3	280	38	37	.6770	43.8
4	318	34	33	.6870	44.5
5	354	30	29	.6715	43.4
6	426	25	24	.6695	43.2
7	500	20	19	.6215	40.1
8	528	13	12	.4150	26.8
9	590	7	6	.2319	15.0
10	614	2	1	.0402	2.6

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 34 D Date: 4/14/10

Effective Head (ft.): 80 Area of Orifice (sq. in.) .5

Rise in Pit (ft.): 3.64 - .58 = 3.06 Initial Weight on Scales (lb.): 1.00

Time (sec.): 735 Discharge (cu. ft. per sec.): .208

Jet H. P.: 1.892

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	154	54	53	.5350	28.3
2	196	49	48	.6160	32.6
3	200	45	44	.5760	30.5
4	275	38	37	.6660	35.2
5	350	33	32	.7330	38.8
6	416	27	26	.7085	37.4
7	500	21	20	.6545	34.6
8	568	14	13	.4840	25.6
9	600	7	6	.2355	12.4
10	608	2	1	.0398	2.1

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 35 D

Date: 4/14/10

Effective Head (ft.): 80

Area of Orifice (sq. in.) .565

Rise in Pit (ft.): Discharge

Initial Weight on Scales (lb.): 1.00

Time (sec.): read from curve

Discharge (cu. ft. per sec.): .2395

Jet H. P.: 2.178

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	126	61.8	60.8	.4985	22.9
2	210	50.	49	.6725	30.9
3	250	45	44	.7200	33.1
4	296	40	39	.7555	34.7
5	354	35	34	.7865	36.2
6	412	30	29	.7825	36.0
7	470	24	23	.7060	32.5
8	590	16	15	.5800	26.6
9	624	8	7	.2860	13.1
10	642	2	1	.0420	1.9

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 36 D

Date: 4/26/10

Effective Head (ft.): 100

Area of Orifice (sq. in.) .2

Rise in Pit (ft.): 4.25 − 1.93 = 2.32

Initial Weight on Scales (lb.): 1.2

Time (sec.): 116.5

Discharge (cu. ft. per sec.): .097

Jet H. P.: 1.101

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	145	35	33.8	.3205	29.1
2	222	32	30.8	.4475	40.7
3	342	29	27.8	.6230	56.6
4	464	26	24.8	.7520	68.4
5	536	24	22.8	.8000	72.6
6	632	22	20.8	.8600	78.1
7	700	20	18.8	.8610	78.3
8	820	15	13.8	.7400	67.2
9	1014	9	7.8	.5185	47.1
10	1196	2	.8	.0629	5.7

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 37 D

Date: 4/26/10

Effective Head (ft.): 100

Area of Orifice (sq. in.): 3

Rise in Pit (ft.): 472 - 101 = 371

Initial Weight on Scales (lb.): 1.2

Time (sec.): 1250

Discharge (cu. ft. per sec.): .1450

Jet H. P.: 1.649

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	106	50	48.8	.3380	20.5
2	250	45	43.8	.7150	43.4
3	330	42	40.8	.8810	53.5
4	348	40	38.8	.8830	53.6
5	364	38	36.8	.8770	53.3
6	426	34	32.8	.9140	55.5
7	476	30	28.8	.8980	54.5
8	556	24	22.8	.8310	50.5
9	700	15	13.8	.6325	38.4
10	770	2	.8	.0404	2.4

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 38 D

Date: 4/26/10

Effective Head (ft.): 100

Area of Orifice (sq. in.): .4

Rise in Pit (ft.): 4.29 - .61 = 3.68

Initial Weight on Scales (lb.): 1.2

Time (sec.): 9.45

Discharge (cu. ft. per sec.): 1940

Jet H. P.: 2.203

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	136	61.8	60.6	.5400	24.5
2	230	54	52.8	.7945	36.1
3	268	50	48.8	.8550	38.8
4	300	46	44.8	.8780	39.9
5	317	43	41.8	.8660	39.4
6	400	37	35.8	.9370	42.6
7	468	30	28.8	.8830	40.1
8	536	21	19.8	.6950	31.6
9	690	11	9.8	.4425	20.1
10	750	2	.8	.0393	1.8

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 39 D

Date: 4/26/10

Effective Head (ft.): 100

Area of Orifice (sq. in.) .5

Rise in Pit (ft.): 4.10 - 1.26 = 2.84

Initial Weight on Scales (lb.): 1.2

Time (sec.): 59.8

Discharge (cu. ft. per sec.): .2420

Jet H. P.: 2.75

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	170	64.3	63.1	.702	25.5
2	260	54	52.8	.898	32.7
3	290	50	48.8	.926	33.7
4	324	46	44.8	.950	34.6
5	354	43	41.8	.969	35.2
6	440	37	35.8	1.030	37.5
7	524	30	28.8	.989	36.0
8	682	21	19.8	.885	32.2
9	726	11	9.8	.466	16.8
10	756	4	2.8	.0139	2.8

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 40 D

Date: 4/26/10

Effective Head (ft.): 100

Area of Orifice (sq. in.) .565

Rise in Pit (ft.): Discharge

Initial Weight on Scales (lb.): 1.2

Time (sec.): read from curve

Discharge (cu. ft. per sec.): .273

Jet H. P.: 3.1

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	190	64.3	63.1	.784	25.3
2	270	54	52.8	.934	30.1
3	292	50	48.8	.933	30.1
4	330	46	44.8	.967	31.2
5	380	43	41.8	1.039	33.5
6	458	37	35.8	1.072	34.6
7	530	30	28.8	1.000	32.2
8	678	21	19.8	.879	28.3
9	728	11	9.8	.467	15.1
10	756	4	2.8	.0139	4.5

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 1 P. Date: 4/22/10

Effective Head (ft.): 20 Area of Orifice (sq. in.) .307

Rise in Pit (ft.): 4.03 − 2.57 = 1.46 Initial Weight on Scales (lb.): 1

Time (sec.): 1035 Discharge (cu. ft. per sec.): .0705

Jet H. P.: .1601

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	116	10	9	.0684	42.7
2	148	9	8	.0775	48.4
3	166	8	7	.0761	47.6
4	186	7	6	.0760	47.5
5	214	6	5	.0700	43.7
6	220	5	4	.0575	35.9
7	250	4	3	.0491	30.6
8	266	3	2	.0348	21.8
9	282	2	1	.0185	11.5

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 2 P

Date: 4/22/10

Effective Head (ft.): 20

Area of Orifice (sq. in.) .442

Rise in Pit (ft.): 3.36-1.62=1.74

Initial Weight on Scales (lb.): 28

Time (sec.): 846

Discharge (cu. ft. per sec.): .1028

Jet H. P.: .2338

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	76	45	17	.0845	36.2
2	100	44	16	.1048	44.8
3	146	42	14	.1338	57.2
4	182	40	12	.1430	61.2
5	214	38	10	.1400	59.9
6	250	35	7	.1144	49.0
7	290	32	4	.0760	32.5

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 3 P

Date: 4/30/10

Effective Head (ft.): 20

Area of Orifice (sq. in.) .601

Rise in Pit (ft.): 4.8 - 2.5 = 2.3

Initial Weight on Scales (lb.): 28

Time (sec.): 810

Discharge (cu. ft. per sec.): .142

Jet H. P.: .349

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	103	50	22	.1488	42.6
2	152	47	19	.1891	54.2
3	184	45	17	.2044	58.6
4	207	43	15	.2035	58.3
5	239	39	11	.1721	49.4
6	270	36	8	.1411	40.5
7	324	32	4	.0848	24.3

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 4 P

Date: 4/29/10

Effective Head (ft.): 20

Area of Orifice (sq. in.) .785

Rise in Pit (ft.): 3.10 - .45 = 2.65

Initial Weight on Scales (lb.): 28

Time (sec.): 702

Discharge (cu. ft. per sec.): .1889

Jet H. P.: .4295

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	112	55	27	.1980	46.1
2	150	52	24	.2355	54.9
3	180	49.5	21.5	.2532	59.0
4	202	46	18	.2376	55.4
5	234	43	15	.2300	53.6
6	264	39	11	.1900	44.3
7	306	35	7	.1402	32.7

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 5 P

Date: 4/22/10

Effective Head (ft.): 40

Area of Orifice (sq. in.) .307

Rise in Pit (ft.): 3.41 - 1.24 = 2.17

Initial Weight on Scales (lb.): 1

Time (sec.): 1063

Discharge (cu. ft. per sec.): .102

Jet H. P.: .464

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	116	25	24	.1822	39.4
2	172	22	21	.2360	50.9
3	226	19	18	.2725	58.8
4	288	16	15	.2825	61.0
5	338	13	12	.2655	57.3
6	364	10	9	.2140	46.2
7	390	7	6	.1530	33.0
8	430	4	3	.0844	18.2
9	456	2	1	.0298	6.4

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 6 P

Date: 4/22/10

Effective Head (ft.): 40

Area of Orifice (sq. in.) .442

Rise in Pit (ft.): Discharge

Initial Weight on Scales (lb.): 28

Time (sec.): read from curve

Discharge (cu. ft. per sec.): .148

Jet H. P.: .6725

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	164	60	32	.3435	51.1
2	206	57	29	.3915	58.2
3	235	55	27	.4155	61.9
4	288	50	22	.4150	61.7
5	338	45	17	.3765	56.0
6	376	40	12	.2510	37.3
7	430	35	7	.1970	29.3

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 7 P

Date: 4/30/10

Effective Head (ft.): 40

Area of Orifice (sq. in.) .601

Rise in Pit (ft.): 5.5 - 2.2 = 3.3

Initial Weight on Scales (lb.): 28

Time (sec.): 810

Discharge (cu. ft. per sec.): .2038

Jet H. P.: .9255

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	110	75	47	.338	36.5
2	186	70	42	.511	55.2
3	248	65	37	.601	65.0
4	259	62	34	.576	62.2
5	315	54	26	.536	58.0
6	393	43	15	.386	41.6
7	484	32	4	.127	13.7

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 8 P

Date: 4/29/10

Effective Head (ft.): 40

Area of Orifice (sq. in.) .785

Rise in Pit (ft.): 4.05-.47=3.58

Initial Weight on Scales (lb.): 28

Time (sec.): 670

Discharge (cu. ft. per sec.): .267

Jet H. P.: 1.213

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	142	90	62	.576	47.5
2	212	80	52	.720	59.4
3	262	75	47	.805	66.4
4	313	65	37	.757	62.5
5	366	55	27	.646	53.4
6	408	45	17	.454	37.4
7	462	35	7	.212	17.5

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 9 P

Date: 4/22/10

Effective Head (ft.): 60

Area of Orifice (sq. in.) .307

Rise in Pit (ft.): 3.53-1.15=2.38

Initial Weight on Scales (lb.): 1

Time (sec.): 944

Discharge (cu. ft. per sec.): .1261

Jet H. P.: .861

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	168	36	35	.3834	44.7
2	208	31	30	.4080	47.4
3	284	29	28	.5210	60.5
4	322	27	26	.5480	63.6
5	356	24	23	.5510	64.1
6	410	20	19	.5100	59.3
7	460	15	14	.4220	49.0
8	504	10	9	.2970	34.5
9	542	5	4	.1418	16.5
10	580	2	1	.0380	4.4

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 10 P Date: 4/22/10

Effective Head (ft.): 60 Area of Orifice (sq. in.): .442

Rise in Pit (ft.): 3.54 - .55 = 2.99 Initial Weight on Scales (lb.): 1

Time (sec.): 81.4 Discharge (cu. ft. per sec.): .1838

Jet H. P.: 1.252

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	150	49	48	.471	37.6
2	234	46	45	.689	55.0
3	282	43	42	.775	61.9
4	314	40	39	.801	64.0
5	352	36	35	.806	64.5
6	404	30	29	.767	61.3
7	435	25	24	.684	54.6
8	500	17	16	.524	41.8
9	560	10	9	.330	26.4
10	600	2	1	.039	3.1

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 11 P

Date: 4/30/10

Effective Head (ft.): 60

Area of Orifice (sq. in.) .601

Rise in Pit (ft.): 5.0 - .7 = 4.3

Initial Weight on Scales (lb.): 28

Time (sec.): 860

Discharge (cu. ft. per sec.): .25

Jet H. P.: 1.706

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	106	102	74	.514	30.2
2	198	95	67	.868	51.0
3	290	86	58	1.100	64.5
4	327	83	55	1.178	69.0
5	351	78	50	1.149	67.3
6	395	68	40	1.033	60.6
7	485	57	29	.920	54.0
8	606	35	7	.278	16.3

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TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 12 P

Date: 4/29/10

Effective Head (ft.): 60

Area of Orifice (sq. in.) .785

Rise in Pit (ft.): 4.28 - .91 = 3.37

Initial Weight on Scales (lb.): 28

Time (sec.): 510

Discharge (cu. ft. per sec.): .3305

Jet H. P.: 2.255

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	107	130	102	.715	31.8
2	252	110	82	1.350	59.9
3	317	100	72	1.492	66.1
4	366	90	62	1.488	66.0
5	428	75	47	1.317	58.4
6	520	50	22	.748	33.2
7	626	35	7	.286	12.7

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 13 P

Date: 4/22/10

Effective Head (ft.): 80

Area of Orifice (sq. in.) .307

Rise in Pit (ft.): 4.67 - .77 = 3.9

Initial Weight on Scales (lb.): 1

Time (sec.): 1330

Discharge (cu. ft. per sec.): .1467

Jet H. P.: 1.332

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	126	50	49	.4040	30.3
2	208	47	46	.6260	47.0
3	260	45	44	.7490	56.2
4	304	42	41	.8154	61.1
5	346	38	37	.8370	62.9
6	430	32	31	.8730	65.5
7	490	25	24	.7690	57.7
8	600	15	14	.5500	41.3
9	670	5	4	.1754	13.1
10	704	2	1	.0460	3.5

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 14 P

Date: 4/22/10

Effective Head (ft.): 80

Area of Orifice (sq. in.) .442

Rise in Pit (ft.): 3.67 − .52 = 3.15

Initial Weight on Scales (lb.): 1

Time (sec.): 745

Discharge (cu. ft. per sec.): .2113

Jet H. P.: 1.92

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	262	61.8	60.8	1.040	54.1
2	330	57.4	56.4	1.217	63.4
3	350	54.	53	1.213	63.2
4	372	51	50	1.217	63.4
5	396	48	47	1.218	63.5
6	440	42	41	1.180	61.5
7	500	35	34	1.111	58.0
8	560	25	24	.880	45.9
9	622	15	14	.570	29.7
10	754	2	1	.049	2.6

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 15 P

Date: 4/30/10

Effective Head (ft.): 80

Area of Orifice (sq. in.) .601

Rise in Pit (ft.): 4.3 - .8 = 3.5

Initial Weight on Scales (lb.): 28

Time (sec.): 588

Discharge (cu. ft. per sec.): .2975

Jet H. P.: 2.703

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	119	130	102	.794	29.3
2	206	125	97	1.305	48.3
3	296	113	85	1.643	60.8
4	327	107	79	1.688	62.4
5	388	100	72	1.825	67.5
6	468	85	57	1.746	64.5
7	538	65	37	1.303	48.1
8	712	35	7	.326	12.1

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 16 P Date: 4/29/10

Effective Head (ft.): 80 Area of Orifice (sq. in.) .785

Rise in Pit (ft.): 4.40 - .45 = 3.95 Initial Weight on Scales (lb.): 28

Time (sec.): 515 Discharge (cu. ft. per sec.): .3835

Jet H. P.: 3.485

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	190	155	127	1.580	45.3
2	294	135	107	2.060	59.0
3	304	130	102	2.032	58.2
4	364	115	87	2.072	59.4
5	452	95	67	1.980	56.7
6	500	75	47	1.538	44.4
7	708	35	7	.324	9.3

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 17 P

Date: 4/26/10

Effective Head (ft.): 100

Area of Orifice (sq. in.) .307

Rise in Pit (ft.): 5.1 − .8 = 4.3

Initial Weight on Scales (lb.): 29

Time (sec.): 1305

Discharge (cu. ft. per sec.): .1648

Jet H. P.: 1.871

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	106	95	66	.455	24.3
2	292	85	56	1.070	57.1
3	404	75	46	1.217	65.0
4	435	72	43	1.222	65.4
5	472	68	39	1.203	64.4
6	538	64	35	1.232	65.9
7	553	60	31	1.121	60.0
8	616	55	26	1.049	56.0
9	668	45	16	.699	37.4
10	772	33	4	.202	10.8

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 18 P

Date: 4/26/10

Effective Head (ft.): 100

Area of Orifice (sq. in.) .442

Rise in Pit (ft.): 4.5-.6 = 3.9

Initial Weight on Scales (lb.): 29

Time (sec.): 805

Discharge (cu. ft. per sec.): .2421

Jet H. P.: 2.752

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	176	120	91	1.048	38.1
2	288	110	81	1.525	55.5
3	390	100	71	1.812	65.8
4	437	90	61	1.741	63.3
5	514	82	53	1.780	64.7
6	580	75	46	1.749	63.5
7	632	65	36	1.485	54.0
8	656	55	26	1.117	40.5
9	758	45	16	.795	28.8
10	818	33	4	.214	7.8

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 19 P

Date: 4/26/10

Effective Head (ft.): 100

Area of Orifice (sq. in.) .601

Rise in Pit (ft.): 4.3 - .5 = 3.8

Initial Weight on Scales (lb.): 29

Time (sec.): 578

Discharge (cu. ft. per sec.): .3282

Jet H. P.: 3.73

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	238	150	121	1.885	50.5
2	298	140	111	2.164	58.0
3	380	125	96	2.385	64.0
4	412	117	88	2.372	63.6
5	502	109	80	2.625	70.4
6	540	100	71	2.508	67.3
7	609	85	56	2.230	59.8
8	670	70	41	1.797	48.1
9	746	50	21	1.025	27.5
10	810	33	4	.212	5.7

TESTS OF WATER MOTORS

THESIS OF

C. BOYLE, JR. A. O. SPIERLING

No. of test: 20 P Date: 4/26/10

Effective Head (ft.): 100 Area of Orifice (sq. in.) .785

Rise in Pit (ft.): Discharge read Initial Weight on Scales (lb.): 29

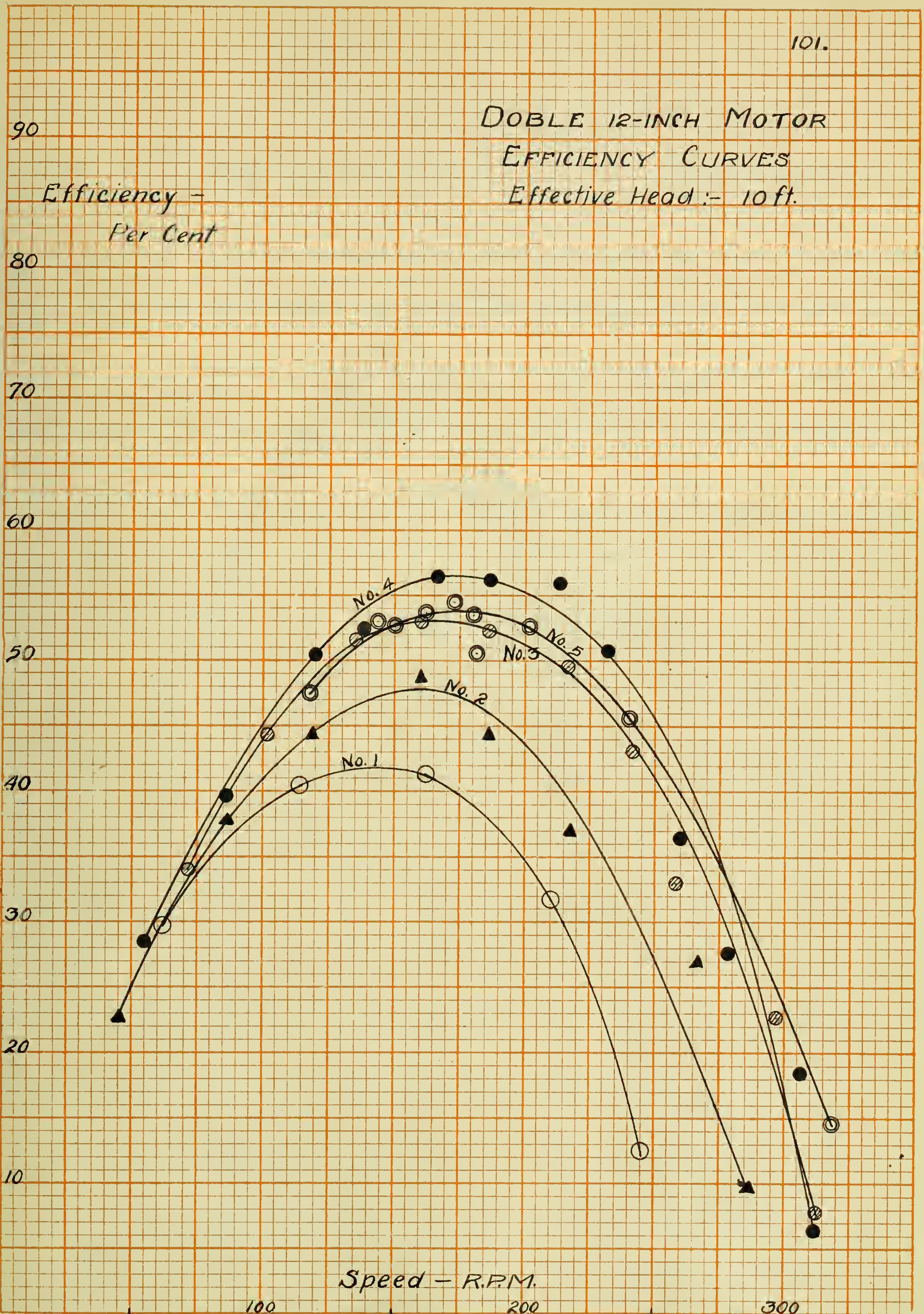
Time (sec.): from curve Discharge (cu. ft. per sec.): .427

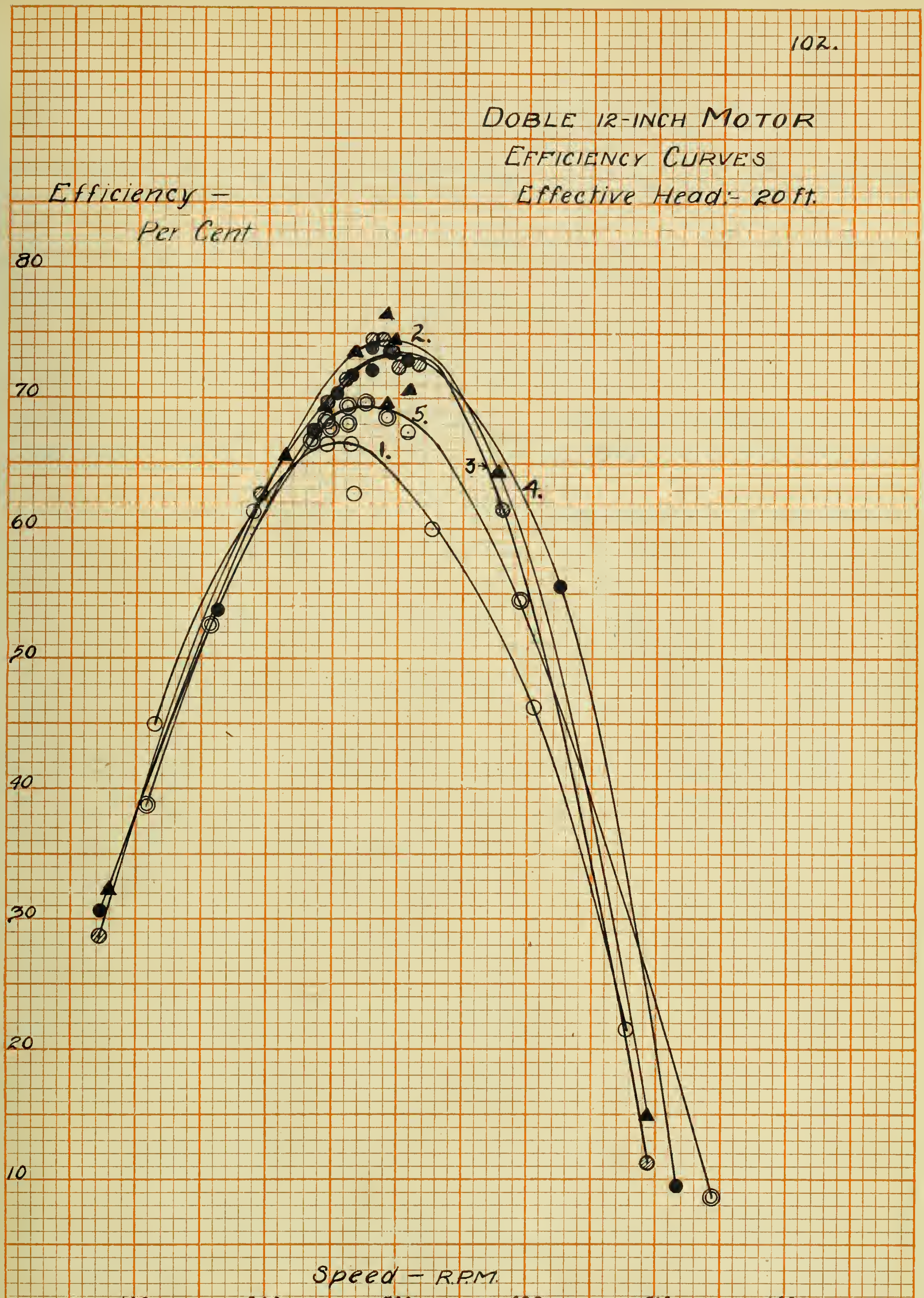
Jet H. P.: 4.85

No.	N Speed R. P. M.	Wgt. on Scales lb.	W Net Load lb.	B. H. P.	Efficiency Per Cent.
1	94	210	181	1.111	22.9
2	192	190	161	2.022	41.7
3	292	170	141	2.695	55.6
4	350	150	121	2.770	57.1
5	396	135	106	2.745	56.6
6	470	120	91	2.800	57.7
7	534	100	71	2.478	51.0
8	594	80	51	1.981	40.8
9	690	60	31	1.400	28.8
10	836	33	4	.219	4.5

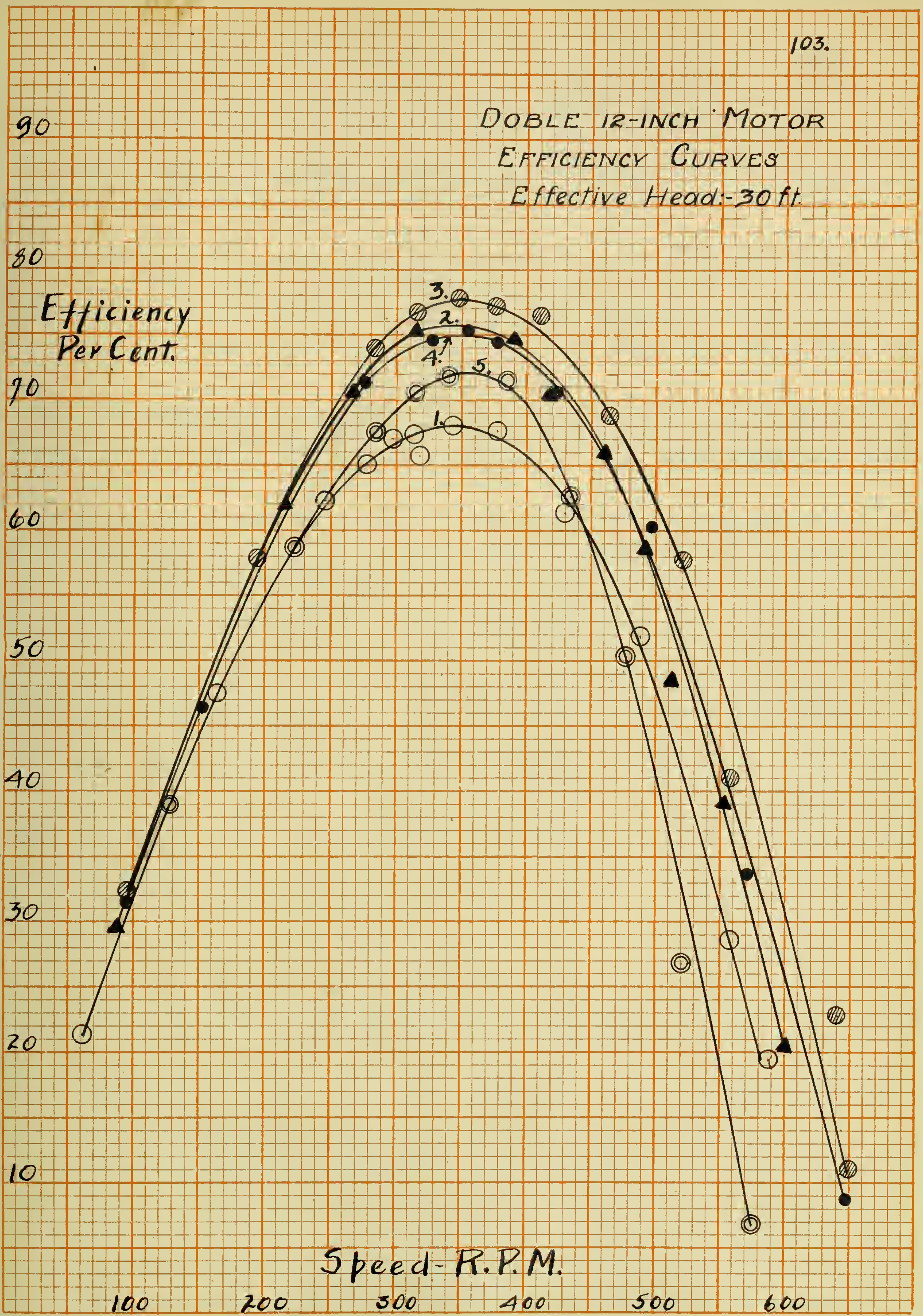
Key to the
Efficiency Curves
Doble Motor

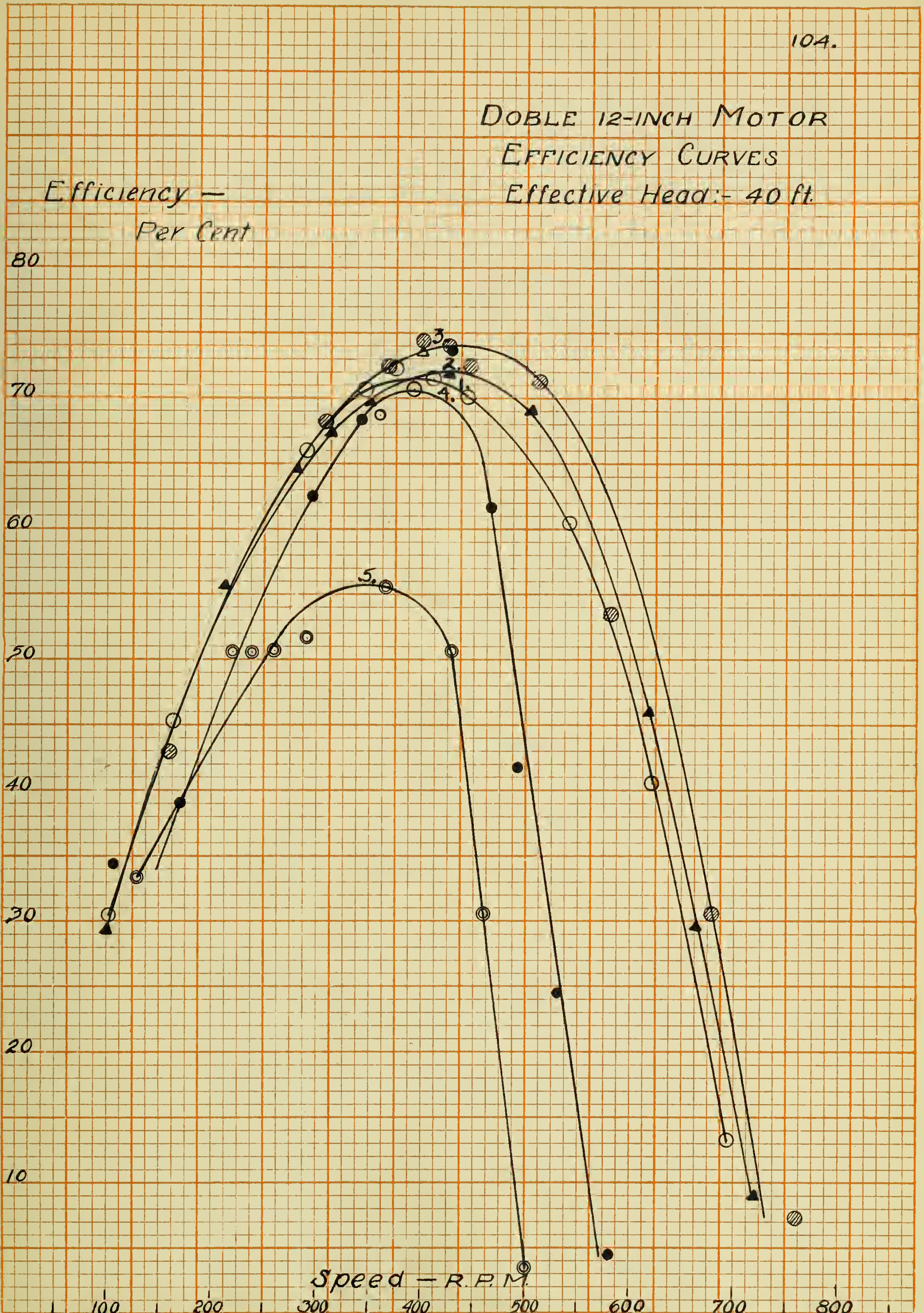
No.	Point	Orifice Area (sq. in.)
1	○	.2
2	▲	.3
3	◍	.4
4	●	.5
5	◎	.565

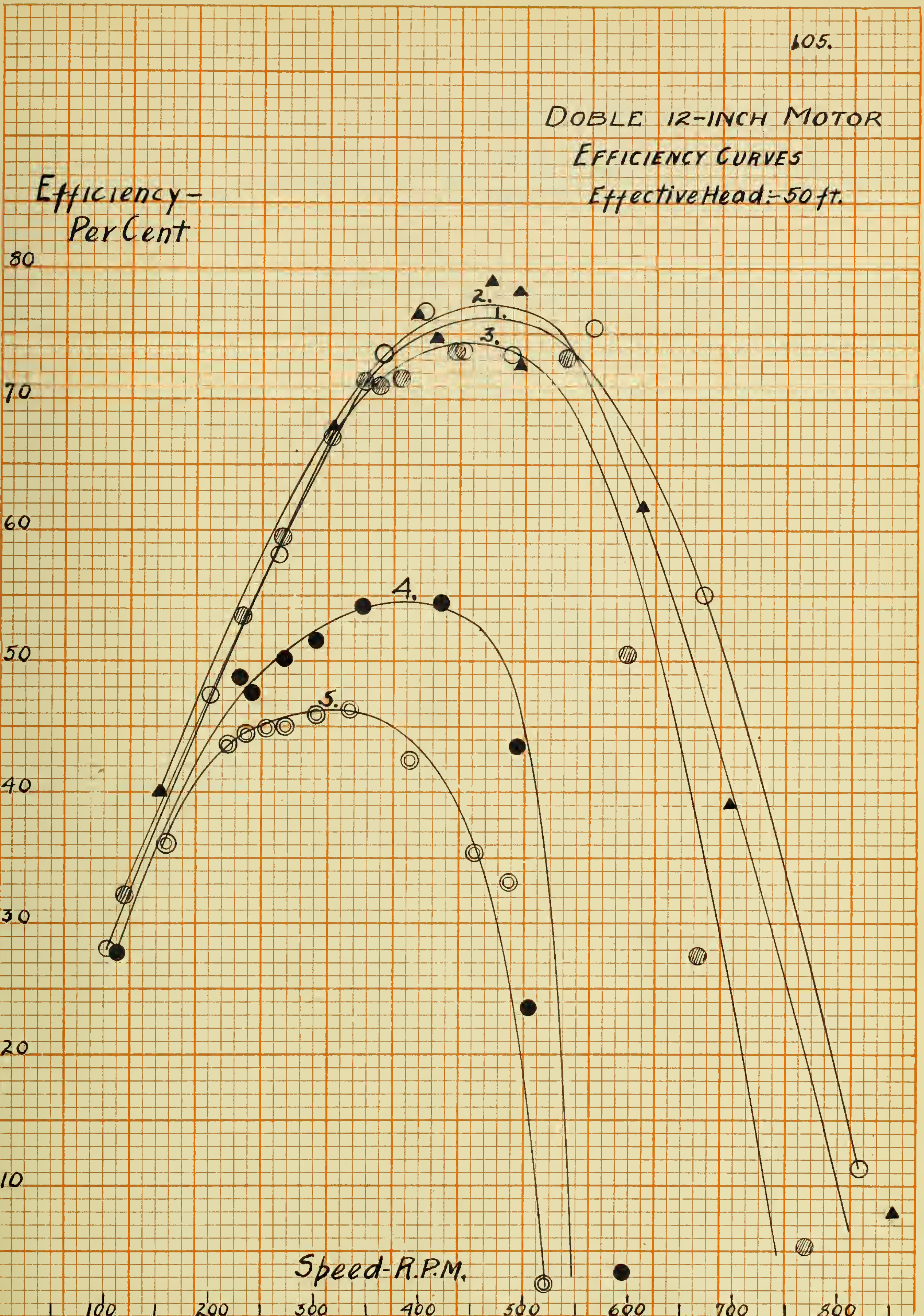

DOBLE 12-INCH MOTOR
EFFICIENCY CURVES
Effective Head :- 10 ft.
Efficiency - Per Cent
90
80
70
60
50
40
30
20
10
No. 4
No. 5
No. 3
No. 2
No. 1
Speed - R.P.M.
100
200
300

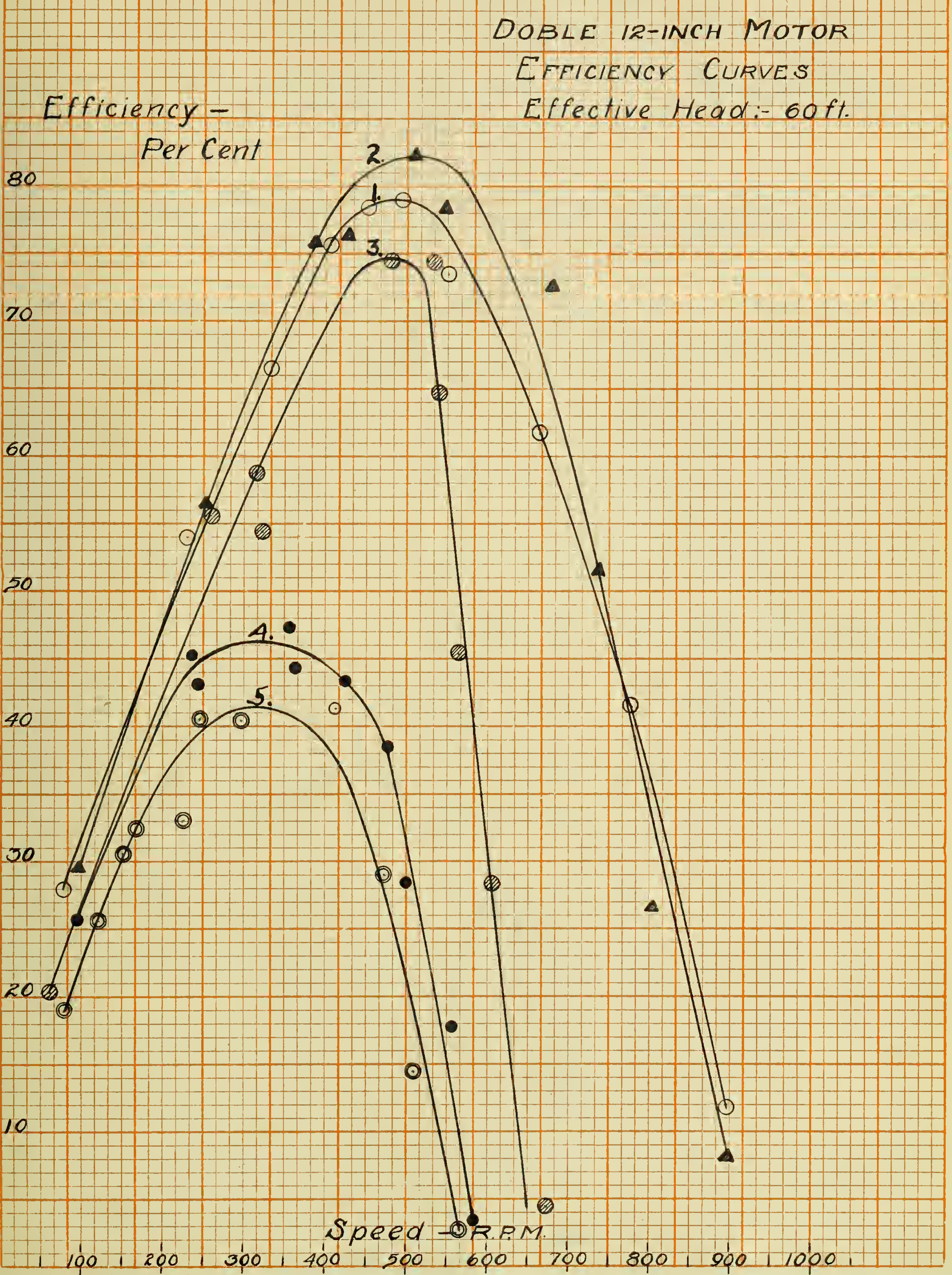


Doble 12-inch Motor
Efficiency Curves
Effective Head:- 20 ft.
Efficiency - Per Cent
80
70
60
50
40
30
20
10
2.
5.
1.
3→
4.
Speed - R.P.M.
100
200
300
400
500
600

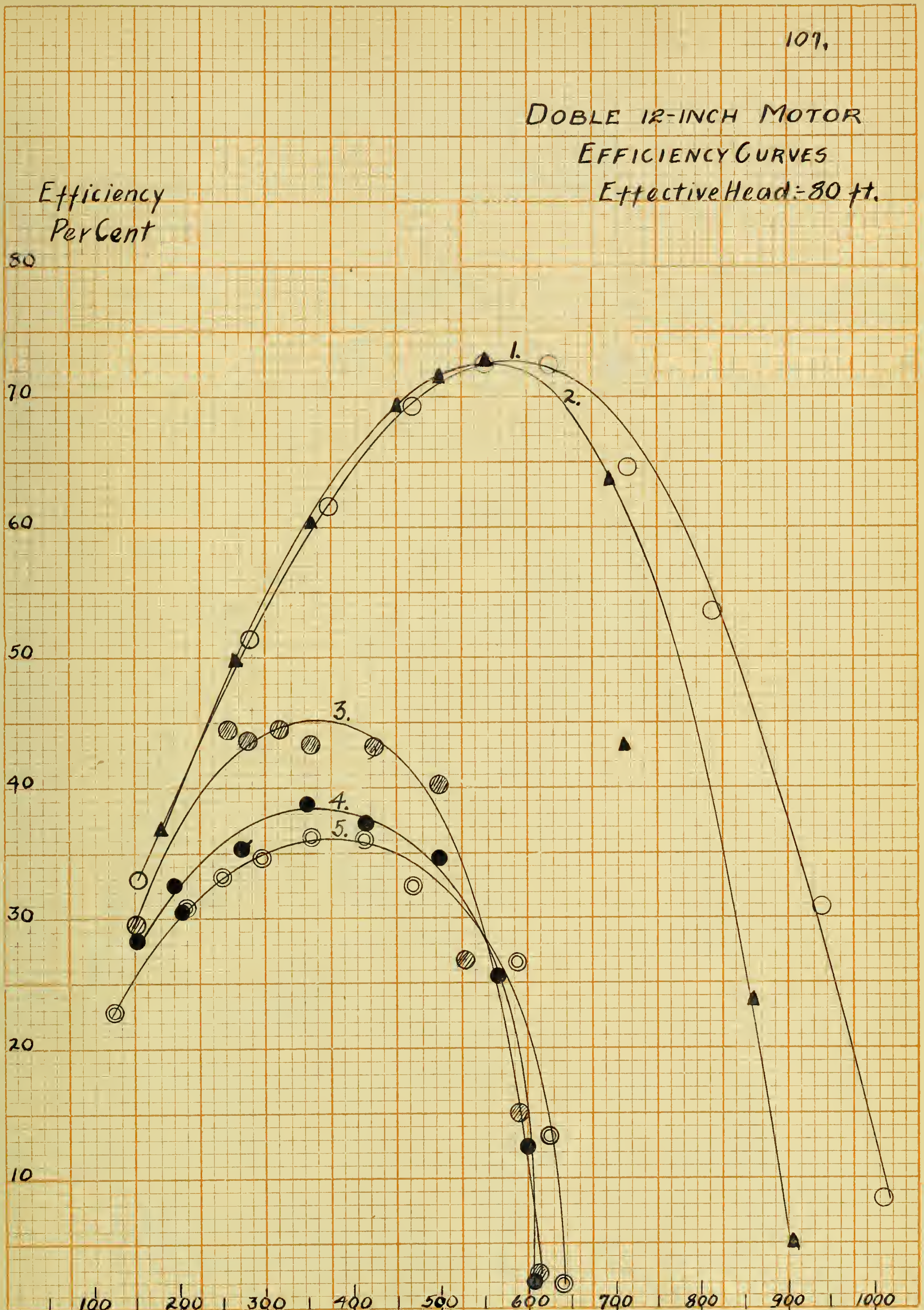

DOBLE 12-INCH MOTOR
EFFICIENCY CURVES
Effective Head:-30 ft.
Efficiency
Per Cent.
90
80
70
60
50
40
30
20
10
3.
2.
4.
5.
1.
Speed-R.P.M.
100
200
300
400
500
600

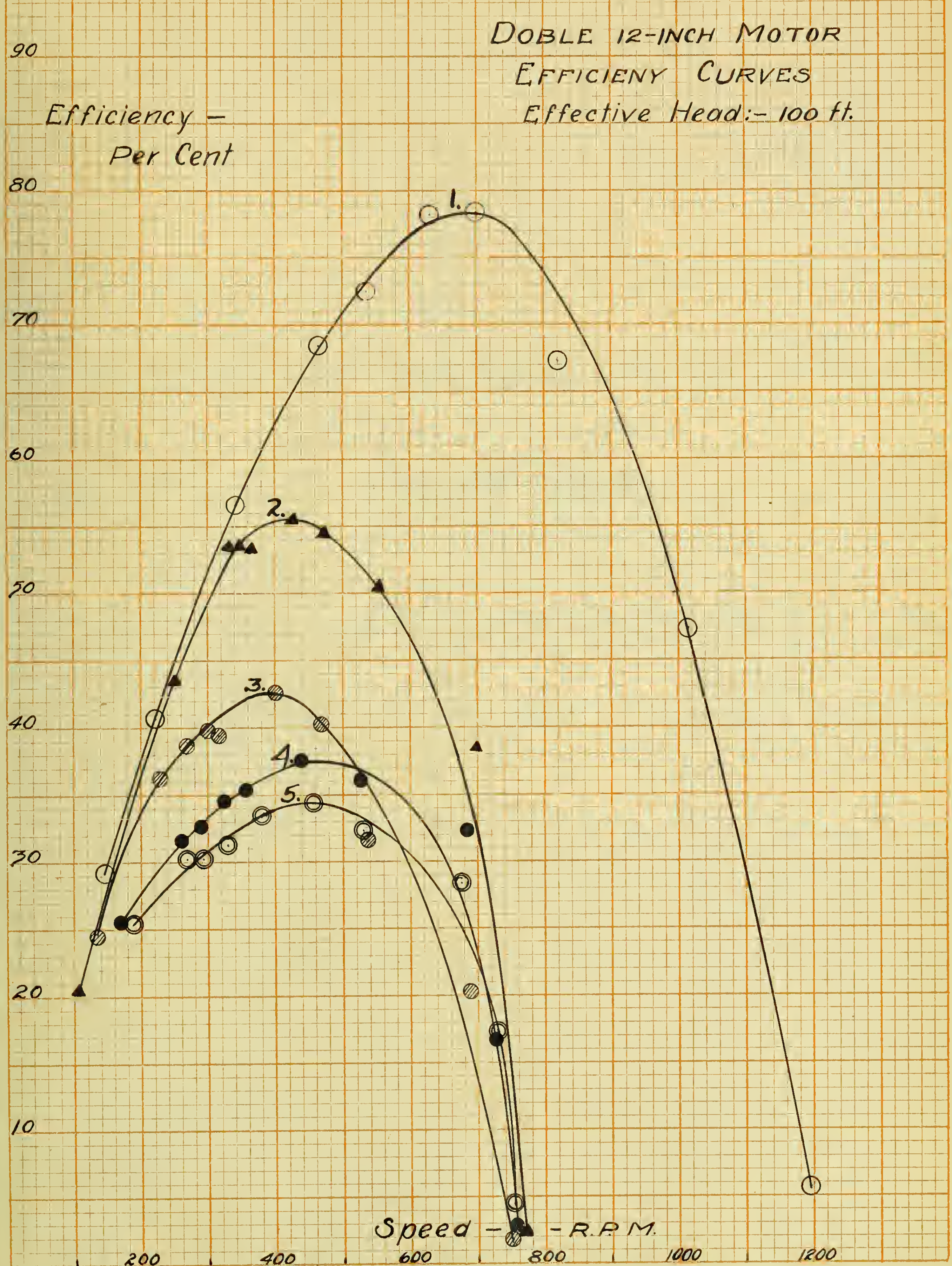

DOBLE 12-INCH MOTOR
EFFICIENCY CURVES
Effective Head:- 40 ft.
Efficiency — Per Cent
80
70
60
50
40
30
20
10
1.
2.
3.
4.
5.
Speed — R.P.M.
100
200
300
400
500
600
700
800


DOBLE 12-INCH MOTOR
EFFICIENCY CURVES
Effective Head:-50 ft.
Efficiency-
Per Cent
80
70
60
50
40
30
20
10
2.
1.
3.
4.
5.
Speed-R.P.M.
100
200
300
400
500
600
700
800



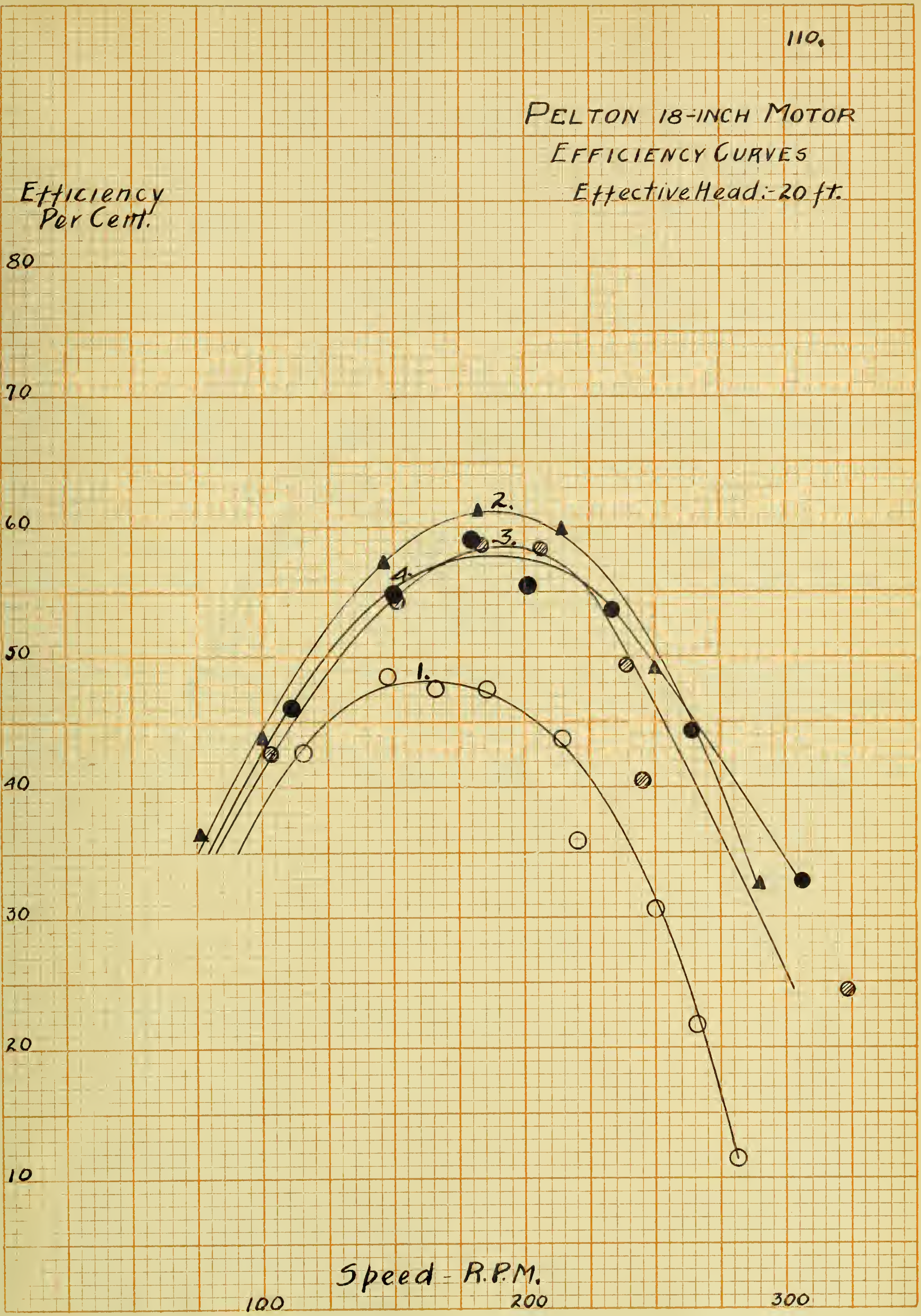
DOBLE 12-INCH MOTOR
EFFICIENCY CURVES
Effective Head:- 60 ft.
Efficiency - Per Cent
Speed - R.P.M.
1.
2.
3.
4.
5.
10
20
30
40
50
60
70
80
100
200
300
400
500
600
700
800
900
1000


DOBLE 12-INCH MOTOR
EFFICIENCY CURVES
Effective Head = 80 ft.
Efficiency
Per Cent
80
70
60
50
40
30
20
10
100
200
300
400
500
600
700
800
900
1000
1.
2.
3.
4.
5.

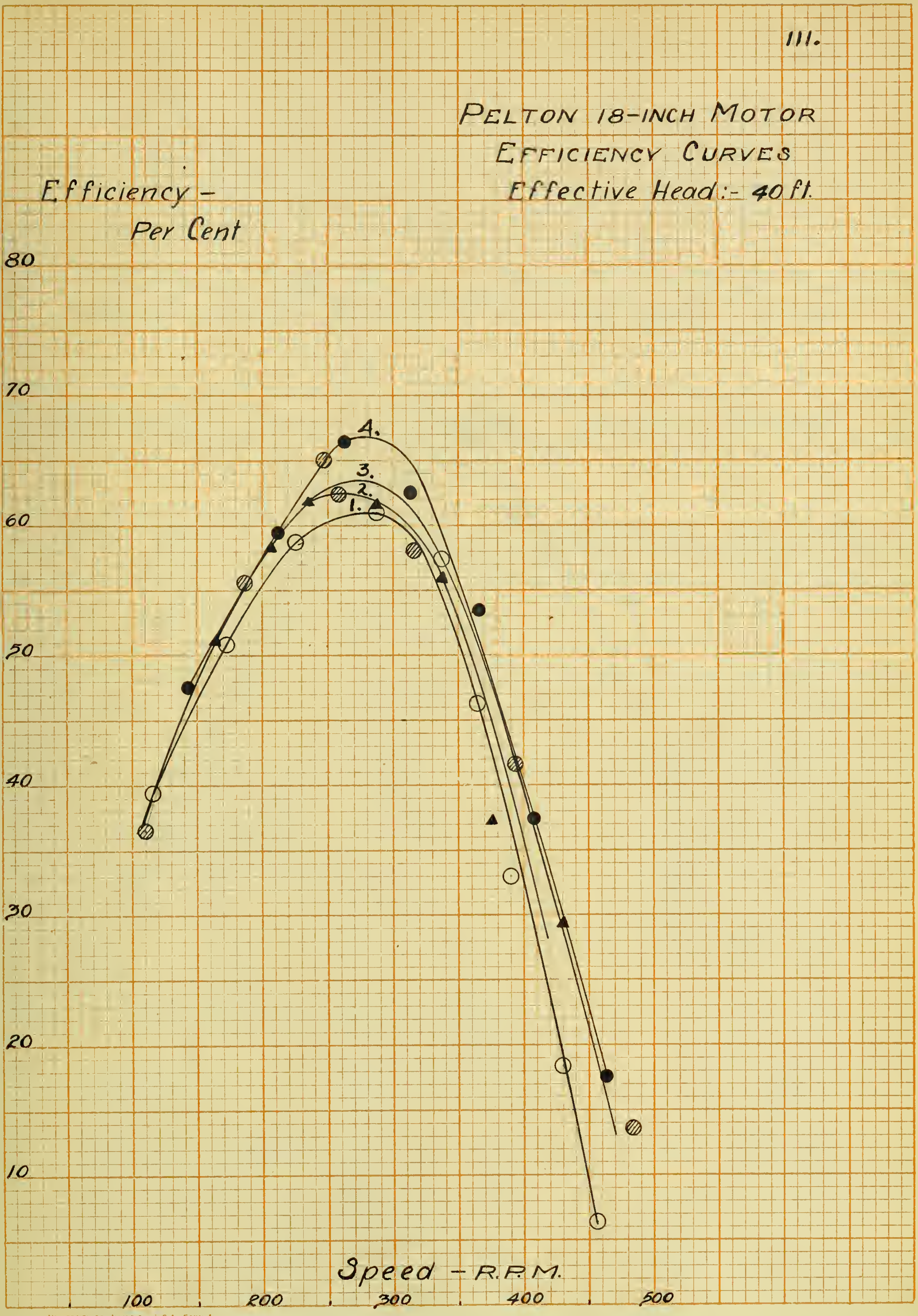

Doble 12-inch Motor
Efficieny Curves
Effective Head:- 100 ft.
Efficiency -
Per Cent
90
80
70
60
50
40
30
20
10
1.
2.
3.
4.
5.
Speed - R.P.M.
200
400
600
800
1000
1200

Key To The EFFICIENCY CURVES PELTON MOTOR

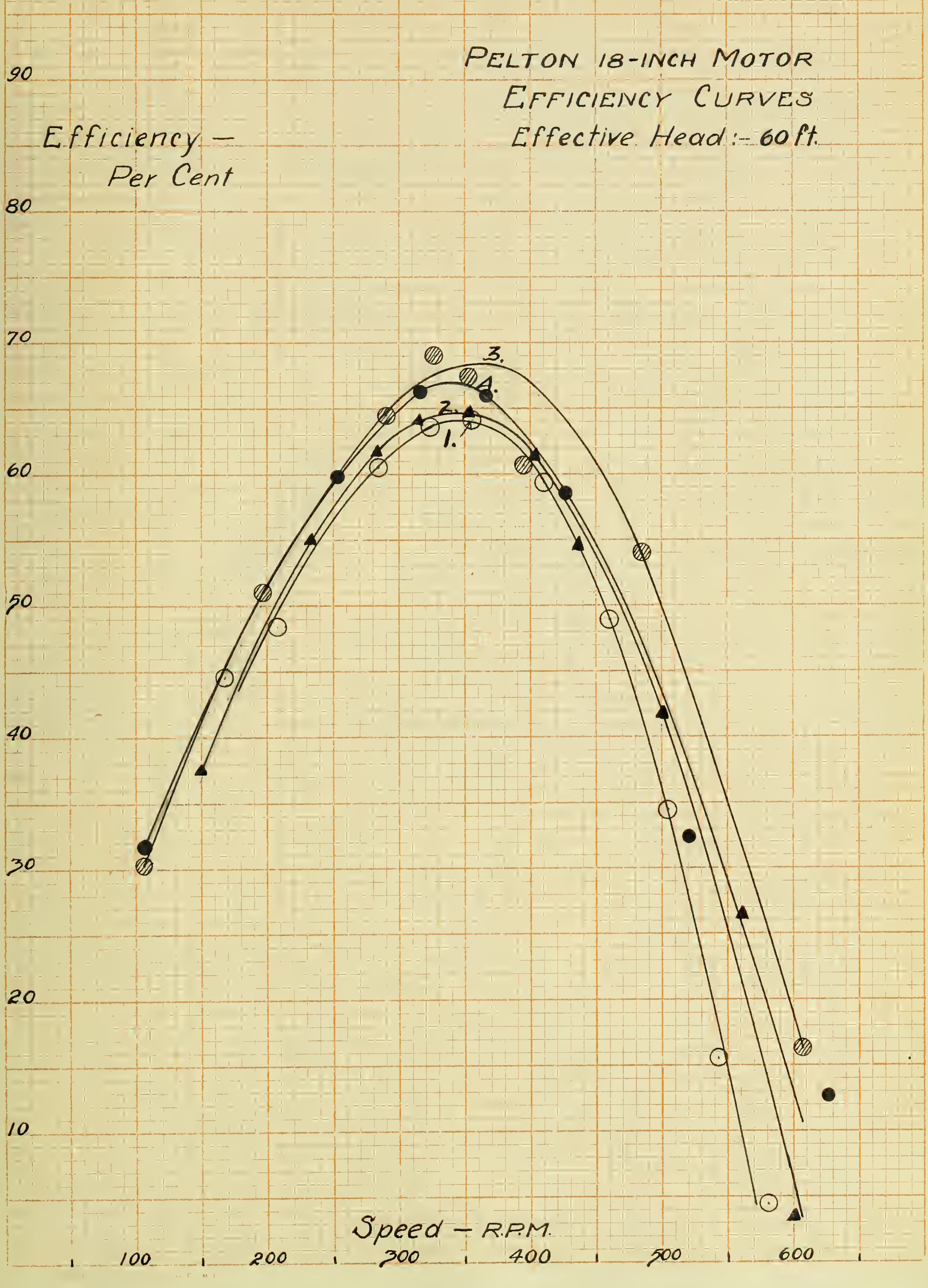
No.	Point	Orifice	
		Diam. - in.	Area - sq. in.
1	○	5/8	.307
2	▲	3/4	.442
3	◍	7/8	.601
4	●	1	.785

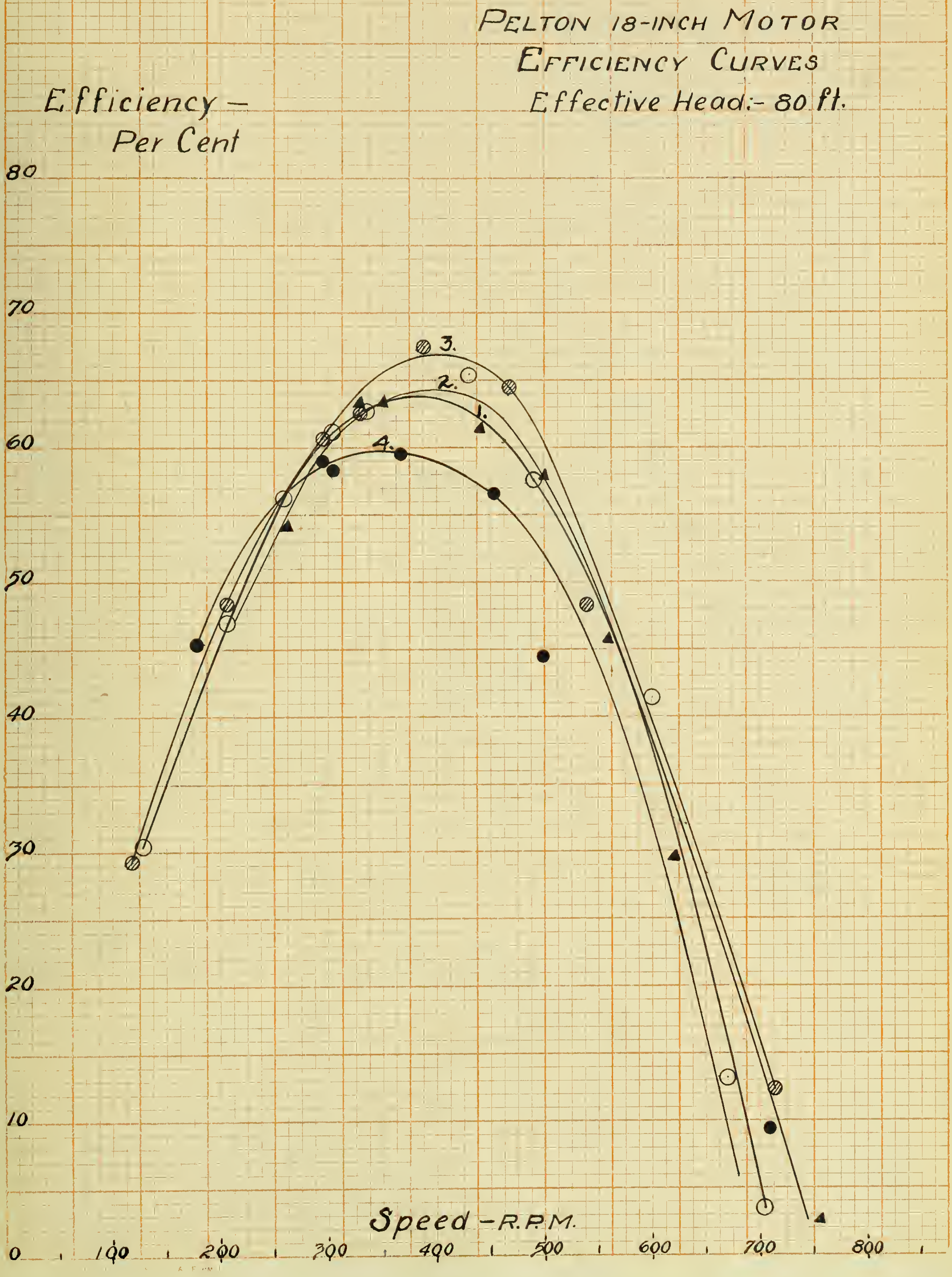


Pelton 18-inch Motor
Efficiency Curves
Effective Head:- 20 ft.
Efficiency Per Cent.
80
70
60
50
40
30
20
10
2.
3.
4.
1.
Speed - R.P.M.
100
200
300

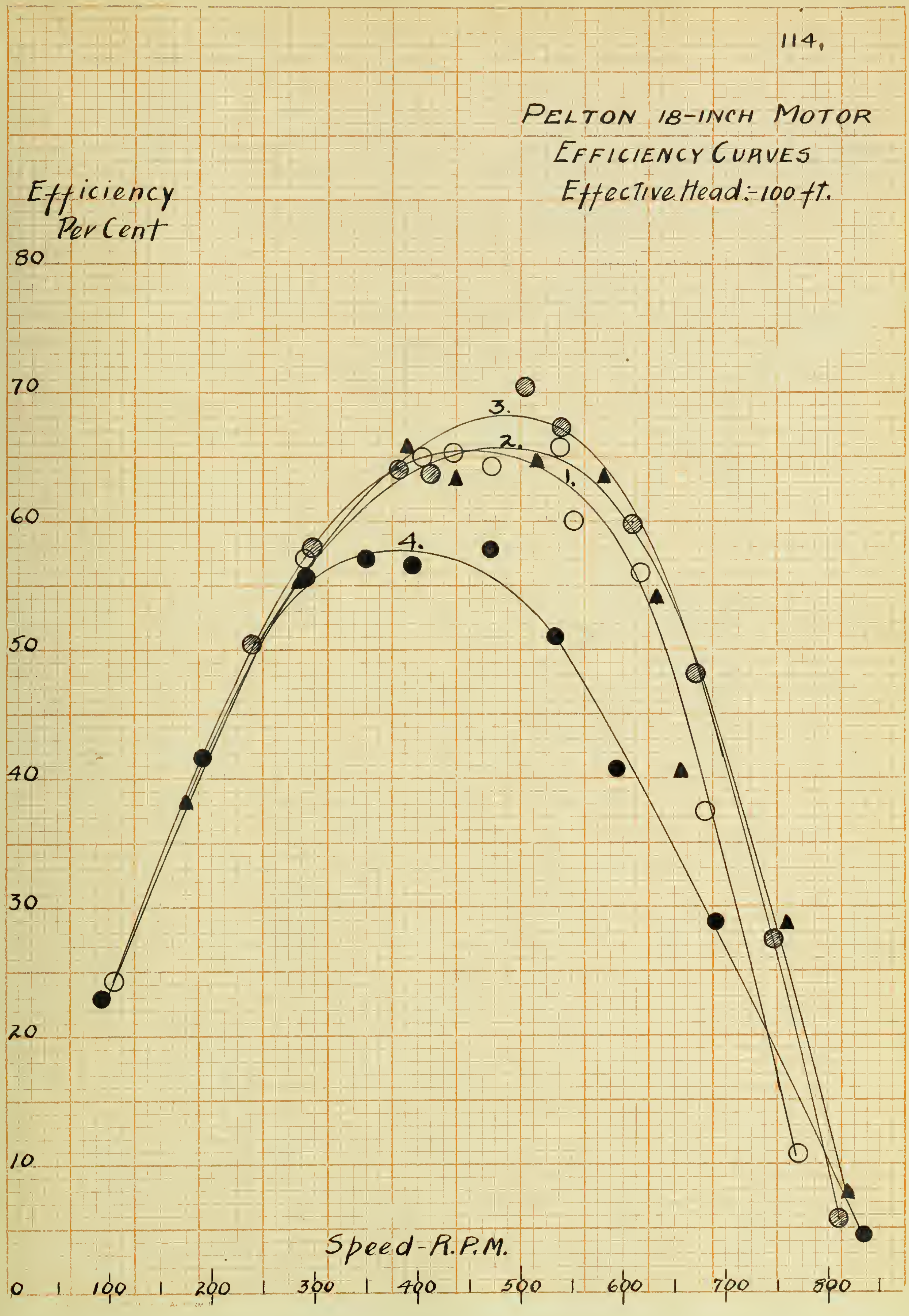


PELTON 18-INCH MOTOR
EFFICIENCY CURVES
Effective Head:- 40 ft.
Efficiency - Per Cent
80
70
60
50
40
30
20
10
4.
3.
2.
1.
Speed - R.P.M.
100
200
300
400
500

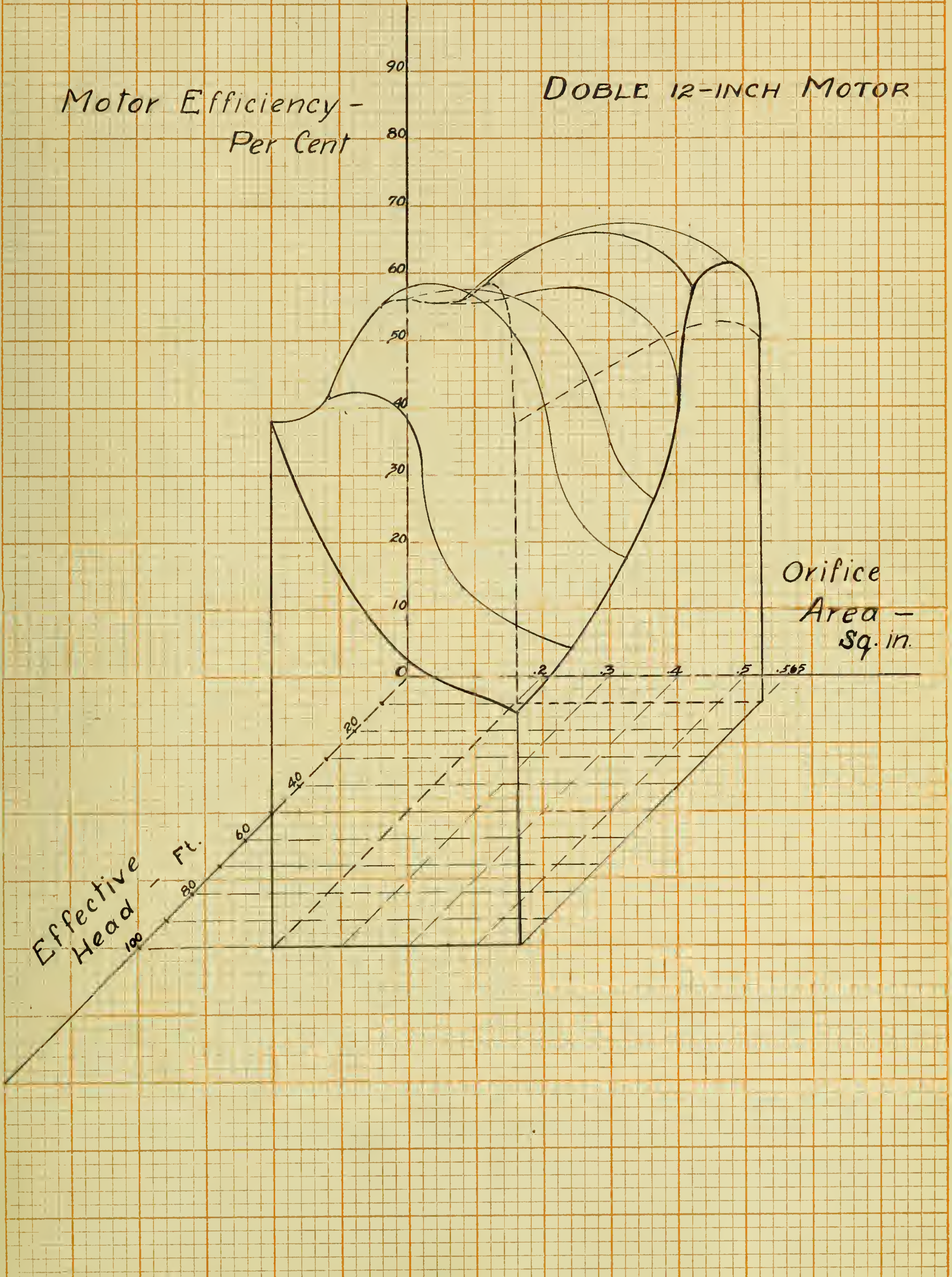

PELTON 18-INCH MOTOR
EFFICIENCY CURVES
Effective Head:- 60 ft.
Efficiency - Per Cent
Speed - R.P.M.
90
80
70
60
50
40
30
20
10
100
200
300
400
500
600
1.
2.
3.
4.

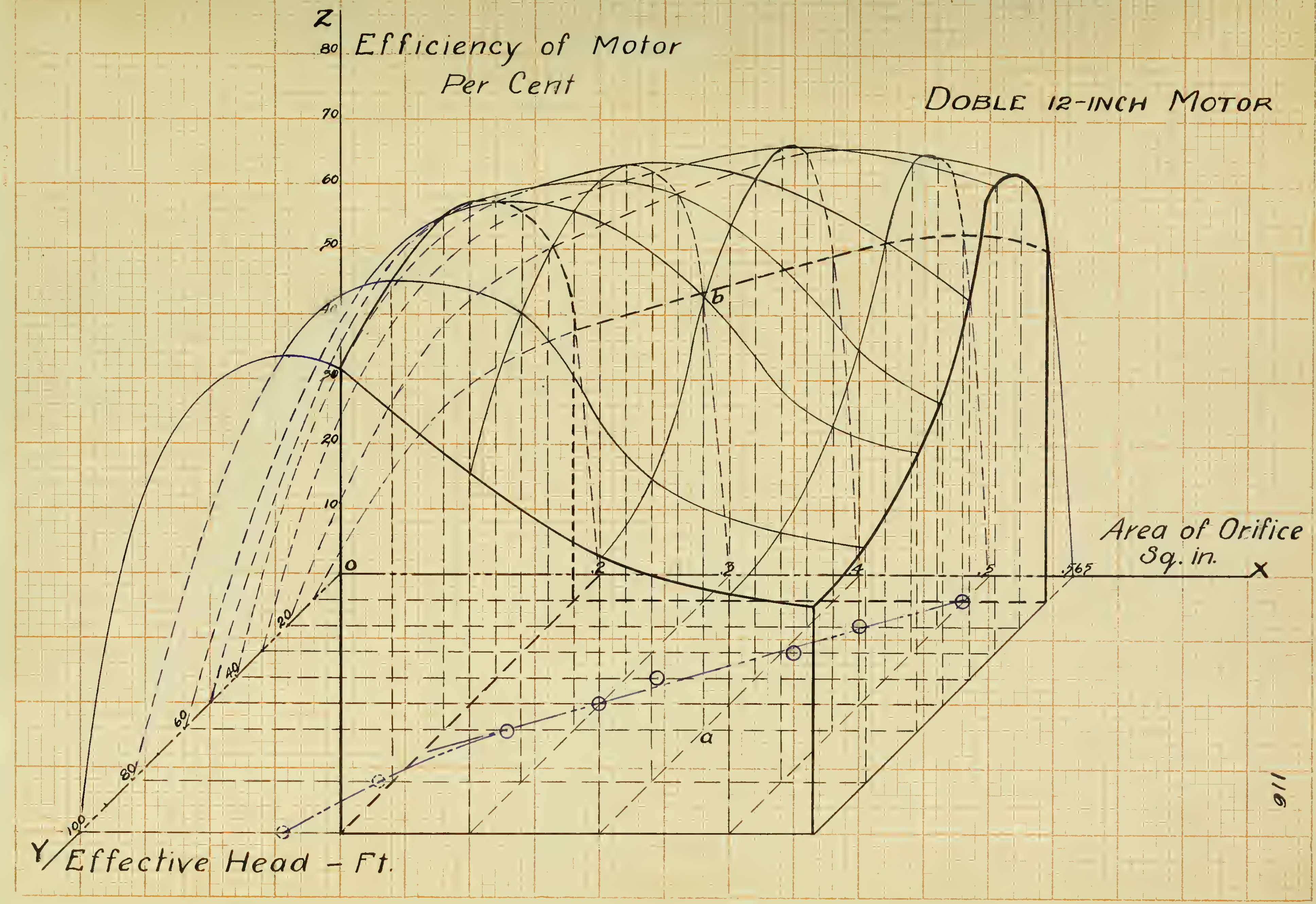


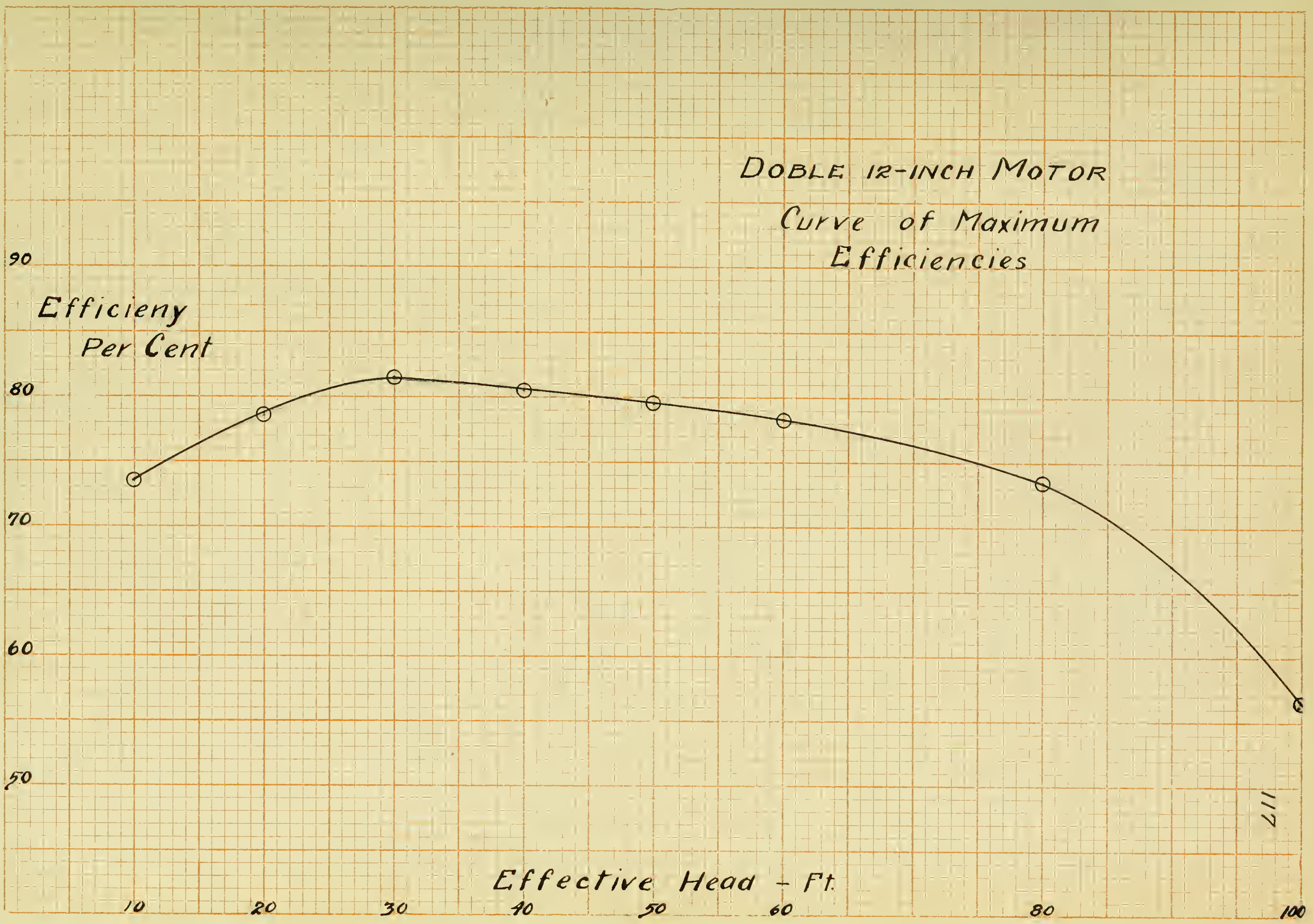
PELTON 18-INCH MOTOR
EFFICIENCY CURVES
Effective Head:- 80 ft.
Efficiency – Per Cent
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
Speed – R.P.M.
1.
2.
3.
4.



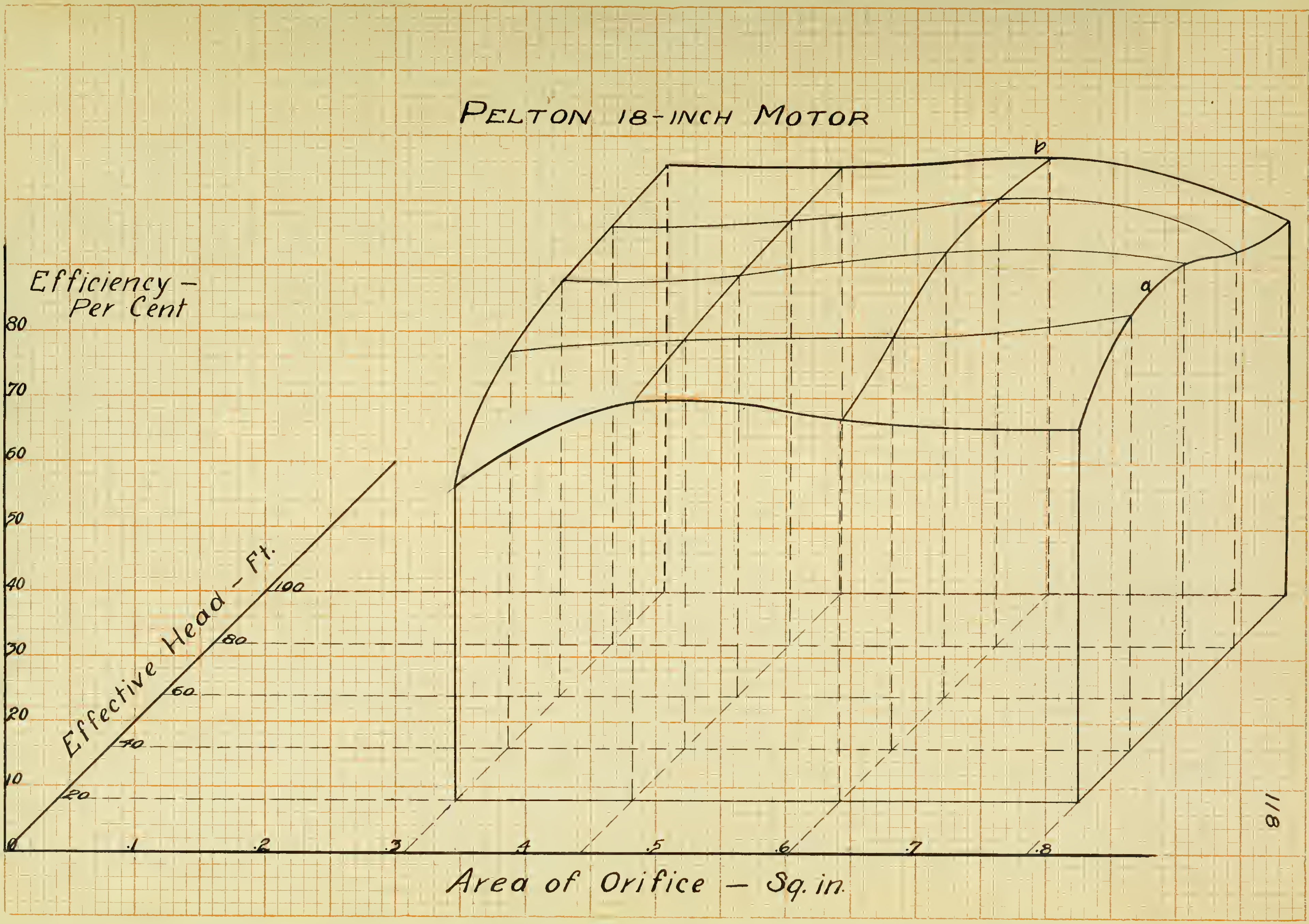
PELTON 18-INCH MOTOR
EFFICIENCY CURVES
Effective Head :- 100 ft.
Efficiency Per Cent
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
Speed - R.P.M.
1.
2.
3.
4.


Motor Efficiency - Per Cent
Doble 12-inch Motor
90
80
70
60
50
40
30
20
10
0
Orifice Area - Sq. in.
.2
.3
.4
.5
.565
Effective Head - Ft.
20
40
60
80
100


Z
Efficiency of Motor
Per Cent
80
70
60
50
40
30
20
10
0
Doble 12-inch Motor
b
a
.2
.3
.4
.5
.565
Area of Orifice
Sq. in.
X
20
40
60
80
100
Y
Effective Head – Ft.



117
Doble 12-inch Motor
Curve of Maximum
Efficiencies
Efficieny
Per Cent
90
80
70
60
50
10
20
30
40
50
60
80
100
Effective Head - Ft.



PELTON 18-INCH MOTOR
Efficiency - Per Cent
80
70
60
50
40
30
20
10
0
Effective Head - Ft.
20
40
60
80
100
.1
.2
.3
.4
.5
.6
.7
.8
Area of Orifice - Sq. in.
a
b
118